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CONTENTS:

	PAGE
The Cost of Electrical Energy	561
Prof. Anthony's Lecture on Incandescent Lamps containing Bromine (*illustrated*)	564
Tests of Reckenzaun Tramway Motors and Gearing (*illustrated*)	567
Testing for Grounds on Incandescent Circuits (*illustrated*) ...	570
Thoughts on Cosmical Electricity (*illustrated*)	571
Correspondence:—	
The Leonard Method of Motor Regulation	573
Personal	574
Mr. Crompton's Paper	574
Electricity Meters	574
Self-Lubricating Bearings	574
Porous Lithanode	574
The Pacific Cable Question	575
Business Notices, &c.	575
Contracts Open and Closed	576
New Books	576
Notes	576
City Notes, &c.	580
Traffic Receipts	580
Share List of Electrical Companies	581
Proceedings of Societies:—	
The Institution of Electrical Engineers	582
Economy in Steam Engine Generation	585
An Estimate of the Distance to which Niagara Water-power can be Economically Transmitted by Electricity	586
New Patents	588
Abstracts of Published Specifications	588

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THE COST OF ELECTRICAL ENERGY.

Mr. CROMPTON'S discourse on the cost of electrical energy must, to the middle-aged electrical engineer, form the subject of reflection and speculation. It summarises the state of the art of manufacturing commercially on a large scale a form of energy which, in his younger days, was dealt with in microscopic quantities. To the younger engineers, it is, perhaps, quite commonplace to talk of kilowatts and Board of Trade units, and the conversion and transmission of hundreds of horse-power by electrical energy. The older electrical engineer, however, cannot help feeling some pride and satisfaction when he looks over the returns of the electricity supply companies, published by us from time to time.

Items such as, "By sale of current, *£50,000*," brings out most forcibly the vast difference between electrical engineering then and now. In the younger days of our elderly electricans current was never considered commercially as a marketable commodity. The cost of the small quantities used then was insignificant compared with the costs entailed in the other branches of the businesses employing it. Now, however, the cost of the current is the all-important item; the current is manufactured, bought and sold, and a certain class of engineers engaged in the business now makes its prime cost a special subject of investigation and study. No better pioneer in such investigations is to be found than Mr. Crompton, and no small share of the credit due for the present advanced state of the art of manufacturing electrical energy is due to him personally, and while we cannot agree with him in all the opinions expressed in his paper, we believe it marks a period in the progress of electrical engineering.

The valuable feature of the paper is the tabulated results of actual experience. We cannot here refer to all of the tables given; for our present purpose we wish to refer only to Table VIII.; in it will be found condensed food for reflection and much significant information for the would-be-improver of the present methods of electrical distribution by low pressure continuous currents.

Referring, first, to the item "Accumulators," in this table, it will be observed that their first cost, exclusive of the buildings, comes out a good second to the greatest first cost—"Mains and services," £65,167, "Accumulators, £15,115," while in the maintenance columns accumulators figure at the head for four years' upkeep at £1,968 and come out in the "per cent. per annum" on cost at 3·25 per cent., second only to the boilers at 5·23 per cent. Now, considering that the accumulators figure so prominently in first cost and maintenance in this table, it becomes a very interesting question whether the game is really worth the candle. What is the exact value of the services rendered for these expenditures on accumulators? Surely some means of arriving at a fair value of the work done by them can be found,

but we confess we cannot see it in this paper. When we look at a load diagram on which the energy supplied by the accumulators to the mains is plotted on the whole energy supplied, it seems to us that the work done by them in nearly every case fills up a very small gap indeed. This part of the subject is worthy of more attention than it receives, and we hope to have it sifted to the bottom as soon as possible. We want both the debtor and creditor sides of the storage account. To warrant the comparatively large expenditure upon them shown in Table VIII., they must play a very important part indeed in any system using them. Any one of the other items may be looked upon as "necessary evils," the accumulators may be evils without being necessary.

Mr. Crompton invited works engineers to discuss the points raised in his paper. We would recommend to their attention this storage question, and the publication of the exact gains or losses attending the use of accumulators. We had no idea that they bulked so largely in the expenditure accounts, in fact it has been generally understood that they formed such an insignificant item in central station plants that whether they gave a satisfactory return for the money spent on their up-keep and first cost or not was a matter of no importance; that is not so if central stations employing accumulators are all like the one from which Mr. Crompton takes his figures.

For some reason or another works engineers are slow to publish the results of their experience with plants under their charge. Descriptive publications are plentiful enough, and disclose a monotonous sameness, but really valuable information, which many engineers must have obtained by experience, is withheld from publication. Nearly every low pressure continuous current plant in existence has an accumulator as a part of its outfit. We would like to see the exact figures obtained from actual practice as to their usefulness. Does their performance in practice warrant their introduction into a central station? We have heard a works engineer, who has had some years' experience with them, say that it certainly does not. If accumulators are to be used in central station work only for the purpose of running a light load in the dead hours of the morning, or as a slight aid at heavy loads, it has been argued ably that a gas engine or two with dynamos would fulfil the purpose at much less first cost and upkeep, and we think the arguments are sound.

We fully expected that Mr. Crompton's paper would have dealt thoroughly with this question of storage at central stations. It is strange that he does not give it due attention, when every minute loss in belt or rope driving, in dynamos, boilers, fuel, and water, is carefully scrutinised.

Storage at a central station is a crying necessity, and must be solved sooner or later on a very different scale from that now practised. If the benefits of storage are to be realised, we must provide capacity enough to enable the whole supply to be drawn from the accumulators. We doubt if much benefit is derived from their use merely as a small auxiliary store, but if employed for the whole supply we can see many vast improvements in central station economics. The engines and dynamos could then be run steadily night and day at full efficiency and full load, and many other advantages would arise which are so obvious that we need not mention them. If it is found advantageous enough to use storage at the expense indicated by Mr. Crompton, it would seem only reasonable to suppose that the accumulators could, with advantage, be applied on a still larger scale; and if there are no gains to be won, but losses to be made, by using them for the whole supply, there must be little or no reason why they should be used at all. Exact figures for calculation are not easily got. Perhaps someone will work out the problem for the benefit of the whole profession. Sometime ago, see REVIEW, data was published for six large stations in Germany, comparing them together in detail in the form of tables of great interest. Strange that in this country such details are carefully concealed, while in America and on the Continent they are openly published and discussed. From these tables we gather that at one station the average watt efficiency varies from 71 to 79·5 per cent., and the loss in the accumulators in per cent. of the total current leaving the station varies from 11 to 14 per cent.; 35 to 62 per cent. of the total energy being sent out came from the accumulators. From these data it would seem that if the whole energy were sent out from the accumulators, the loss would be 20 per cent., and the question is simply whether this loss would or would not be counterbalanced, or much more than counterbalanced, by the savings in the boilers, engines, dynamos, attendance and fuel, if the whole supply were drawn out.

The ½ per cent. more or less efficiency of dynamos, engines and boilers of different types, and the description of well-known machinery, forms the subject of one paper after another, *ad nauseum*, without introducing anything of real value so far as adding to the knowledge on the subject. Central station engineering is of such magnitude that it is apt to dwarf everything else. But after all, the machinery and appliances used in it are not very interesting to electricians as a body; as a rule, the central station plant does not show the latest developments in electrical engineering. The motto over the central station is often "No innovations;" and perhaps it is best so, for innovations are often experiments. On the other hand, the central station engineer should be open minded and clever enough to recognise and adopt improvements in every direction which time surely brings forth.

In the words of Mr. Crompton, "electrical supply has now passed from the stage of estimate and talk into that of commercial enterprise." That being so, its development is now along commercial and financial lines, and its interest to the scientific investigator and electrician is considerably lessened. At the same time there are many other branches of electrical engineering still in the stages of "talk and estimate," and requiring all the ability, energy, and skill of the foremost electrical engineers to land them on to the stage of "commercial enterprise." Electromotive power, electric traction, electro-metallurgy, and electro-chemistry, and may we add, electric storage, are a few of these branches.

We must turn now to another important subject dealt with by Mr. Crompton. Between the claims made by makers of boilers and other special apparatus, and the results obtained in practice, there are usually very wide discrepancies. Too frequently the practical knowledge of the everyday man is locked away in his own pocket-book, and engineers who have not had special means of undertaking tests for themselves are thrown back for information upon professorial and similar tests, which, though conducted with every honest intention, cannot be called working tests. The result

is that when a test shows figures indicating a specially high or a specially low efficiency, the data of such tests are apt to be fastened upon as something essential to economy in all future practice, or something to be avoided. Some such result it must have been that led Mr. Crompton to doubt the usefulness of the hydrogens in bituminous coals.

We have not the slightest hesitation in affirming that Mr. Crompton could advance cases to apparently prove his contention as to the necessity of a small coal consumption, in Lancashire boilers, per square foot of grate, if economy is to be secured. Neither have we any hesitation in affirming that equally opposite conclusions could be contended for from other cases. With a view to show the futility of such arguments, and indicate the wideness of the limits of practice between which good results can be and are obtained, we may call attention to figures—the practical correctness of which may be granted—that have been obtained from certain tests, carried out with the object of gaining information simply of commercial value to the steam users themselves, and not with any intention of proving the superiority of one appliance over another.

Two sets of tests are involved and two sets of boilers. In the one case there was an economiser, in the other none; but, contrary to Mr. Crompton's dictum, the economiser existed only in the case of the smaller consumption of fuel per square foot of grate. It is chiefly to the very wide difference in the rate of fuel consumption that we would draw attention, accompanied as it is with so close an equality in evaporative results. All the tests were carried out by one engineer, and the water measured by the same meter. The engineer had the word of the makers that the meter was correct, but beyond this did not himself calibrate it, as his object was comparison of fuels, &c., not evaporative power. The shortness of the tests could not be avoided; each test began with steam up and just enough fire to ignite the fresh fuel. The results do not therefore profess an accuracy in decimals, but are accurate for our purposes. In the first set, a Lancashire boiler with a good chimney 70 feet high, furnaces 36 inches diameter, and a grate area of 22½ feet, was fired by a mechanical stoker of the coking description with Yorkshire fine slack coal for six hours on two occasions, the coal being more dusty in the second test than in the first.

The rates of combustion were respectively 25½ and 22½ lbs. per square foot per hour, and the evaporation in the two cases 12·38 and 10·63 respectively from and at 212°. Curiously enough, the better evaporative efficiency was with the higher rate of combustion, against which is to be set a slightly cleaner fuel. Smoke was *nil*. The main flue had a temperature of 610° by pyrometer, though we have not over much faith in this instrument. The object of these two tests was to ascertain whether an existing boiler could be depended on to do a certain anticipated duty; there was no question of rivalry, no choice of material, and no outsiders were interested.

In the second series of tests to which we refer, the object was to ascertain the value of different coals as a guide to the price per ton to be paid. They are interesting, because the rate of combustion is very low, and the evaporation is good, and so these tests are apparently contradictory to the first-named.

There were two 7 feet Lancashire boilers with a total grate area of 66 square feet. They were hand fired for about eight hours. The chimney was 90 to 100 feet high, and there was an economiser of 64 pipes. Tested with four coals, viz., small coking Staffordshire, small Midland coking, Durham slack, and good Welsh, the rates of combustion per square foot of grate were respectively 6·3 lbs., 5·9 lbs., 5·96 lbs., and 5·88 lbs. In each case the same engine was working at its usual duty. The evaporation in each case, from and at 212°, was as follows—10·49 lbs., 10·86 lbs., 11·87 lbs., and 12·29 lbs. With the exception of the economiser being small, these tests may be said to be based on Mr. Crompton's ideal method of working Lancashire boilers at low rates of combustion, whereas with a quadruple rate of combustion the mechanically stoked boiler with no economiser, named above, gave higher results. We are not here particularly concerned with the prices of the four coals, but at the prices ranging in the market at the time, the Durham slack was fully 25 per cent. cheaper than the best Welsh per 1,000 gallons evaporated. It was nearly as much cheaper than the Midland small coking coal. The Staffordshire coal again came out 14 per cent. dearer than the Welsh, and our friends inferred that the Staffordshire and Welsh coals were rated too high for their duty; that, practically, a ton of one good coal was as good as a ton of any other sort of good coal at equal price per ton. They found that small Welsh was a little dearer than good Welsh, and as a further test they tried coke breeze and small coal mixed, and found that the result of last year's coal strike had been to so enhance the cost of coke breeze as to run this up to a price that was beyond its evaporative effect.

So far as we can summarise these tests, we should say they appear to show the advantages of mechanical stoking, in regard to both economy and smokelessness; for in the hand fired light combustion tests there was some smoke, whereas there was none with the machine stoker. The main conclusion, however, and that which we set out to emphasise, is that boilers may be worked at or near maximum efficiency between a far wider range than can steam engines, and no such close figures can be laid down as data in respect of fuel consumption, grate area, chimney height, or any other matter except paying a fair and good wage to the stoker, so as to obtain an efficient and good man.

The tests with good Welsh and small Welsh appear to show that Welsh coal suffers more than ordinary bituminous coals by reduction to slack and dust. The enormous rise in the price of coke breeze near London that has taken place is evidence that a fuel of real value may lie undiscovered by the multitude for a long time; but that having been discovered, it is apt to rise in price beyond what it is really worth. This would point to breeze being a fuel of limited quantity, and not one on which much reliance can be placed, or to use which it is now worth while going to any very great outlay in special appliances.

The Douglas and Laxey Coast Electric Tramway.—The first section of this tramway, extending in the Isle of Man from Douglas to the Glen of Groudle, was opened for traffic on Thursday last week in fine weather. The cars ran the distance of four miles along the new marine drive with remarkable smoothness. No friction was observable, and the trial was in every way a complete success. Messrs. Mather and Platt, of Salford, have constructed the line and put in the electric installation. It is expected that the line will be completed to Laxey at the end of June or the beginning of July.

PROF. ANTHONY'S LECTURE ON INCANDESCENT LAMPS CONTAINING BROMINE.

PROF. ANTHONY'S lecture, which we commented upon in our issue for May 4th, was read and discussed on the same evening both in New York and Chicago. A more interesting discussion, which may be read almost *verbatim* in the *Transactions* of the American Inst. Elec. Engineers for April, 1894, and the main features of which we are about to lay before our readers, it has seldom been our lot to peruse. Several speakers expressed their opinions, and almost all of them had some novel phenomenon to describe, or some pertinent criticism to put forward. Amongst the more prominent members who took part in the discussion, either by speech or written communications, were Prof. Elihu Thomson, Mr. Howell, Mr. Colby, President E. J. Houston, and others. One novel incident in the proceedings was that the two meetings, 1,000 miles apart, were, for the first time, placed in telephonic communication, the respective chairmen presenting hearty congratulations to their distant fellow members.

The discussion at New York was opened by Prof. Wm. L. ROBB. This speaker agreed with Prof. Anthony that what was most needed at the present day was a lamp that did not fall appreciably in candle-power. In a large establishment, or hall, the light was maintained pretty uniform, owing to the frequent renewal of lamps, but in a room in a dwelling house, *e.g.*, where only three or four lamps were used which started at, say, 16 C.P., and in six or eight weeks gave only 12 C.P., there was much need for improvement. He was glad to see that these bromine lamps gave a prospect of improving the present state of things. The forced tests which had been shown demonstrated the advantage these lamps had in standing hard usage. With reference to the blackening of the bulb, he fully agreed that it was due chiefly to the evaporation of the carbon. He did not think it could arise from "air washing" or convection currents, as in that case it should be proportional to the temperature. To support this contention he referred to the paper by Prof. Weber, of Zurich, on the temperature of filaments at different degrees of incandescence. The latter professor found that the temperature of the filament of a 100-volt Edison lamp (new type) running at 3·04 watts per candle was 1,573° C., and that when run at 2·25 watts per candle the temperature was 1,610° C., or an increase of only 37° C. He did not think that so small a difference of temperature in that part of the scale would account for the difference in the rate of blackening at these respective efficiencies. And the same remark held good with regard to the Crookes radiation effect, which could not be so materially augmented by a difference of only 8 volts, the amount required for producing the difference in efficiency. But the amount of evaporation at these temperatures might be very different. Very slight differences in either pressure or temperature were known to affect in a marked manner the rate of vaporisation of ice, camphor, &c., and why should not the same hold good with carbon? Of the three explanations put forward to account for blackening, the one most in accordance with experimental facts was the evaporation theory pure and simple.

A communication by Prof. ELIHU THOMSON was then read. He agreed with Prof. Anthony's view as to blackening, and had held it for several years. "It had been known for a long time that the highest vacua were not so beneficial to the life of lamps as a more moderate exhaustion; and Edison had patented the use of a residual chlorine atmosphere in about 1883." Perhaps bromine or mixtures of it and other vapours might be better than chlorine. Another thing that was well known to lamp manufacturers —though we think not to many others—was that lamps starting with rather low vacua often improved their vacua automatically during the run. "My opinion as to the cause of this improvement has long been that the first beginning of the production of soot or separation of solid carbon at normal potentials, causes, by the separated carbon particles, absorption of the residual gas so as to improve the vacuum. Fine carbon has, as is known, a powerful gas-absorbing tendency, and although the amount formed may be so slight as to be totally imperceptible in the bulb, it may still be present in sufficient quantity to have the effect noted.

"The bearing of these facts on the sustained brilliancy of a lamp started with a lower vacuum is evident. If the *gas present be gradually taken up, the efficiency of light production will rise and compensate for the change in the filament as time goes by.*" He agreed with Prof. Anthony that the carbon left the filament in the form of vapour, but he thought it must condense at once just outside the filament. To support this contention he referred to a certain 25-volt lamp in his possession, which had been accidentally connected for a moment to alternating mains of large carrying capacity, and at a potential difference of 1,000 volts. The filament survived the shock, and the glass bulb was clean and clear; but there exists "a flocculent mass of soot which is coherent, and falls about within the lamp. It is a comparatively large mass, and at first surrounded the filament as a delicate mantle, evidently formed by a dense evolution of carbon vapour condensing immediately around the carbon in the vacuous space. Here the age coating (?) was too dense to reach the sides of the bulb. The lamp, however, is a significant example of the normal action of vaporisation highly intensified. The filament retains its steely lustre." Reference was next made to carbon shadows which, it was asserted, *do* occur, just as do those produced by metal vapours. It will be remembered that we called attention to the fact in our comments on the lecture.

As to the allusions in the lecture that the carrying of a current through a vacuum seems to appertain to electrolytic action, Prof. Thomson supported the idea, and spoke of a lamp he had containing copper terminals, in which fine hair-like metallic projections had formed. These had evidently been produced by the current passing through the vacuous space between the wires, and lamps had been known to short-circuit from this cause. [These copper branches were of frequent occurrence in the once familiar Bernstein heavy current lamps.] Some further remarks were made relative to obtaining metallic mirrors from arcs between metallic electrodes in vacuo, and to the experimental possibility of softening and bending carbon sticks at very high temperatures.

Another communicated item of the discussion, by Mr. E. P. THOMPSON, was next read. It dealt entirely with the question of the action of mercury vapour on the incandescent carbon filament. He had made crucial experiments on the subject which had not been published. Some mercury was boiled in a lamp for half an hour, and when all air had been expelled, and only mercury vapour, apparently at atmospheric pressure, remained, the filament was raised to whiteness, or probably 3,000°, and was continued running for half an hour. No combustion or action of any kind, however, was perceived to occur between the mercury and the carbon, although the experiment was repeated with 25 lamps. "But," says Mr. Thompson, "how about slow combustion?" While the mercury vapour was escaping the lamps were sealed and cooled, and the remaining mercury was allowed to run into a little tube. "These lamps lasted almost uniformly only about 50 hours, because the filaments were *slowly* consumed by the mercury vapour. The condensation of the mercury had left so perfect a vacuum as to the air, that a trace of the mercury vaporised, and formed an attenuated atmosphere of mercury. This result agrees with those of others made in other directions. For example, it has been noticed by those who exhaust lamps, that it is not well to continue the exhaustion too long, for the lamps do not last so long, and the reason is thought to be that when the vacuum is too complete, a point is reached where the mercury of the pump vaporises and surrounds the filament. Mercury appears, therefore, as a heavy gas, which should not exist in an incandescent lamp." No mention is made as to whether these mercury vapour lamps were more deeply blackened than ordinary lamps. We must confess to not being wholly convinced as to the accuracy of the deduction here drawn, and think that it is still unproved that the presence of mercury vapour was the cause of the short life of these or other highly exhausted lamps to which reference is made.

Mr. J. W. HOWELL, whose experience in lamp manufacture is second to none, then spoke at considerable length, firstly on the subject of lamp blackening, and then on the influence of gases in the lamp bulb. He pointed out the error of supposing that shadows and irregularity in the depth of carbon deposit in lamp bulbs did not exist. The blackening theory propounded by Prof. Anthony, *i.e.*, by the evaporation of carbon, was the one generally accepted by lamp manufac-

turers. But all blackening is not caused by evaporation in rectilinear lines, as was demonstrated by a lamp which he exhibited, wherein there was a piece of glass, the underside of which was blackened, although completely shielded from the carbon. Another lamp was shown in which was a line which looked like the shadow of the filament, but which passed "around the lamp in a plane perpendicular to the plane of the filament." In another lamp there were several bands running around the lamp in that way which he likewise could not account for. But the usual manifestation was a line round the globe in the same plane as the filament, and the reason it did not occur in all lamps was because the filaments were not all of them regular, but twisted. A platinum incandescent lamp was shown in which a well defined shadow, caused by evaporation, was seen.

Mr. Howell also remarked on the fact that carbon could be easily softened and bent when heated under a strain, and it would become quite rigid again in its new shape. He had seen "an incandescent filament in an upright position so softened by an excessive current that it would not sustain its own weight; it wilted, so that the parallel legs crossed one another. When the current was turned off the carbon was perfectly rigid in its new position."*

"Blackening," said Mr. Howell, "is not the chief cause of the fall of candle-power in lamps; some lamps lose their candle-power and show very little blackening, while other lamps get quite black and lose little candle-power; 115-volt lamps will lose their candle-power, and blacken very little indeed. This loss is due to changes in the structure of the filament, or in its surface, which reduce the candle-power considerably, with very little blackening. The filaments of low volt lamps are much more stable than the filaments of high volt lamps; low volt lamps often show considerable blackening, with very little loss of candle-power." Mr. Howell seems here to try to minimise the evil of blackening as much as possible. Whilst it is readily admitted that decrease in candle-power does not result from this cause alone, there are few experts on incandescent lamps, especially those who have taken filaments out of blackened bulbs, and put them into new ones, who will not reluctantly maintain that blackening is a very serious, if not the most serious, defect attending incandescent lamps.

Mr. Howell next dealt with gases in the lamp bulb, and called attention to the fact that the partial vacuum of a lamp would improve with use. The cooling effect of the gas diminished, and the candle-power rose, the rise depending upon the amount of gas in the bulb. "A rise of 30 per cent. could be produced in this way. If too much residual gas be left in a lamp, the opposite effect will be produced, the candle-power will fall at first, then rise a little, and finally start off in a straight line. These effects are produced by the residual gases which are left in the lamp in its normal exhaustion, not by other gases, such as bromine." The lamp tests comparing the vacuum and the bromine lamps were then criticised at some length. The lamps that had been selected, viz., 55-volt of 25 C.P. to 30 C.P., were the best and most durable lamps that could be made. Tests should have been given of 115-volt lamps, which were much more generally used, and were much harder to make. He admitted that the bromine lamp tests gave good results as to candle-power, but they broke too quickly. The vacuum lamps they were compared with were poor lamps, and the comparison was not therefore a fair one. He then showed a test, carried on under his supervision, of 18 good 50-volt 32-C.P. vacuum lamps, which were run at 3 watts per C.P. for 1,000 hours without breakage. At the end of 100 hours the candle-power had risen 15 per cent., and at the end of 1,000 hours it was still above the initial candle-power. This result could not have been obtained with high-volt lamps. The bromine lamps selected by Prof. Anthony were very badly volted, and all those run at the higher voltage had broken; the others which lasted were run below their candle-power. There was one thing he admired about the test:—"The pressure was held constant to $\frac{1}{100}$th of a volt, which is extremely accurate work, and not in keeping with the rest of the work done." He also had tested some Novak lamps, but they were not of 50 volts; they were 115-volt 16-C.P. lamps, and run at 3·5 volts per candle. The results obtained were very different from those given by Prof. Anthony. They did not maintain their candle-power, but dropped right down, and they also broke very rapidly. Out of 19 lamps, half had broken in 500 hours. It took those lamps just 250 hours to arrive at the candle-power at which Prof. Anthony said they were practically dead, and at 400 hours they had lost 80 per cent. of their original candle-power; 400 hours was the limit of life admitted by Prof. Anthony for vacuum lamps, when they lost only about 20 per cent. He did not agree with Prof. Anthony, however, that a lamp which had lost 20 per cent. was practically dead. He also did not agree that bromine prevented the wasting away of carbon and the increase of its resistance; though he admitted that blackening was prevented. The 115-volt lamp he had tested increased in resistance very materially, and, besides, these bromine lamps had some essential disadvantages. The heat generated in the lamp meant loss of energy, and to get the same efficiency in light the lamp must be run much higher. That necessarily shortens the life, as is abundantly shown. The result is, the disadvantages of the bromine lamps are greater than its advantages.

Mr. Hammer, who followed, pointed out that the "phantom shadow" on lamp bulbs which had been noticed by Prof. Elihu Thomson had been seen by him in the lamps of 12 different makers. He showed some photographs of these "phantom shadows," which were scarcely visible to the eye, but which photography brought out distinctly.

Mr. S. E. Doane, who represented the Thomson-Houston Company, wished to emphatically confirm all that had been said by Mr. Howell. Previous to the appearance of the Novak lamp, the Thomson-Houston Company had tested for their own information the effect of various gases, including chlorine, in lamp bulbs. The candle-power rose, and then fell again, just as Mr. Howell had shown. The candle-power of a lamp ought not to rise extremely, and it ought not to fall extremely. As to the volatility of carbon, a theory he had long held, he quoted as follows from a paper which had been read by Prof. Thomson:—"The writer has long been convinced that in a well exhausted lamp it is due almost entirely to evaporation by high temperature. Just as ice near its melting point, and even far below that, evaporates in vacua, and even in dry air, so carbon, practically fixed at low temperatures, acquires in vacua a certain volatility at an increasing rate with temperature." It, continued Mr. Doane, is the only theory at present that satisfactorily accounts for the blackening of incandescent lamps. With regard to the behaviour of Novak lamps under forced conditions, he had that morning selected at random a 110-volt 16-C.P. lamp from an unopened package of those lamps, and had run it at 140 volts, an equivalent in per cent. increase in voltage to the 65-volt test of Prof. Anthony. At the start this lamp took ·757 ampères. After running five minutes it increased to ·799 ampères, and the candle-power rose from 59 to 71. The cause of this was not due to a change in resistance, which *increased* a little, but was simply due to improvement in vacuum, which latter was noticed from time to time by tests on an induction coil. "Had the test been continued it would, had it lasted long enough, have fallen in candle-power, and in time have reached its first candle-power. Had we made only the first and last measurements we should have said the candle-power had been maintained constant throughout the run, while really it had fallen at least 17 per cent." The initial C.P. of the lamp was really 71. As a rule, the rise occurs soon after starting, and lamps taken for comparison should be taken at a point where the maximum candle-power has been reached. It is important, therefore, to test frequently during the early run of a lamp.

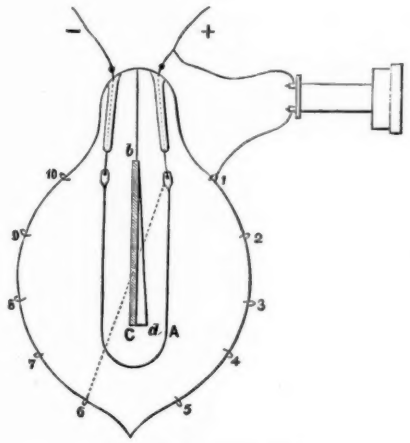
Mr. T. J. W. Olan said he wished to call attention to two facts; one was that carbon at a white heat will take up one equivalent of carbon and be transformed into monoxide of

* The present writer had an interesting experience some years ago, demonstrating this softening property of carbon. A comparatively thick and short ∩-shaped filament of low resistance, mounted on wires, was placed in a horizontal position in a hydro-carbon vapour and a heavy current was turned on, a resistance which was supposed to be included being accidentally short-circuited. The result was a bright momentary flash without any smoke. On examining the filament it was found broken at the bend with a gap of about ¼ inch between the ends, the latter being drooped downwards in a short arch, evidently caused by gravity. The rest of the filament was quite straight and sound. The experiment was repeated with another similar filament with precisely the same result.

carbon; the other is that if we lead carbon monoxide through a tube that is heated yellowish white, carbon dioxide and carbon dust will be formed. These two facts, he thought, would account very reasonably for the blackening of lamp bulbs, as at the filament the residual oxygen or carbonic dioxide would form carbonic oxide, while a short distance from it the yellowish white temperature would exist, and then the carbonic oxide would be decomposed. Mr. Olan does not seem, however, to take into consideration another fact quite as certain as those he here refers to, viz., that chemical reactions only occur when the surrounding physical conditions are favourable; and it does not at all follow as a matter of course that in practically vacuous space, with gaseous matter in very rapid motion, the conditions required for the reactions he cites, do exist. Mr. Olan proceeded to remark on the fact that bromine lamps did not blacken. "Why? Because bromine is one of the few elements that do not combine directly with carbon by heat, or as far as known, under any circumstances." Nitrogen is present in the ordinary lamp bulb, and this gas at high temperatures is "known to combine with carbon just as well as oxygen, and here we have another possible cause of the blackening of the globes as a result of chemical reaction." We fear we are not very profoundly impressed by the purport or accuracy of these remarks.

The next speaker, Mr. Colby, described some very interesting experiments he had made in Mr. Weston's laboratory on the effect of gases in lamps, deposition of carbon inside the bulb, the conductivity of the residual gases when the filament was running, and other subjects. Mr. Howell had said that the only beneficial effect obtained from the use of bromine in lamps was to reduce the blackening, but there was another. About 11 years ago he had much difficulty in making some 125-volt 125-C.P. lamps owing to short-circuiting occurring inside the bulbs, and the only way he had found to obviate the difficulty was either not to completely exhaust the lamps, or to introduce some inert gas. Several gases had been tried, amongst others being bromine, and several of the chlorine compounds. Chloroform was finally decided upon as giving the best results. One result of using this compound was that the chlorine combined with the mercurial vapour in the bulb. As a matter of fact, in one bulb quite a heavy deposit, white in colour, formed and hid the filament from view; but on heating it with a Bunsen burner, the bulb became clear. A decrease in the blackening of the lamps was also noticed. Mr. Colby's remarks here become so interesting that we print them *in extenso*.

"It was a matter of some experiment to determine what proportion of vapour it was expedient to leave within the bulb, and one simple method which I adopted at that time suggested certain lines of research which I have been unable to follow, and which I would like to mention here, in the hope that some of you who are still in the incandescent lamp field can take it up. I have felt certain that there were two causes, as we all know, for the diminution in the candle-power of the lamp. The first was the vaporisation of the carbon, and its subsequent deposition upon the bulb reducing the transparency of the same, and the second was the change in the condition of the carbon filament itself. The vaporisation, of course, is a function of the temperature to which the filament is subjected, and is to a very much less extent dependent upon the difference of potential between the terminals. However, working at higher potentials this difficulty increased. The other defect was due, as I said a moment ago, to the change in the structure of the carbon itself. Apparently a deposit of carbon was formed upon one leg of the filament, which carbon was separated from the opposite leg. I was interested in ascertaining whether I could prevent this deposit, and so maintain the normal appearance of the filament by the interposition of a shield between the two legs of the carbon. I supported a glass plate between the two legs of the carbon filament, and suspended the lamp vertically, the loop hanging down, and noted the deposition of carbon upon this shield between the two legs of the filament. That, of course, would be naturally expected. But a curious feature of it was this, that the deposit was chiefly on one side, and that the depth of deposit over this glass shield increased from the top of the shield down towards the bottom, that is, the loop of the lamp being in this form (A, see fig.), and the shield being down here (*b*, *c*), the depth of the deposit was heaviest at the bottom instead of heaviest at the top where the greatest difference of potential existe. The figure represents the general outline of the lamp. It was known at that time as the Mogul lamp. A number of them were placed in the Equitable Building, 120, Broadway, in 1883 and 1884, and attracted considerable attention at that time on account of the large candle-power of the lamps. They were made up to 600 candle-power. The difficulty we had in the first construction of these lamps was due to a discharge directly across from stub to stub. I then



Mr. Colby's Experiment.

put here a glass plate (*b*, *c*), which was supported on a neutral wire at that point to increase the distance between the terminals and prevent any direct path between the two. The deposit that was formed upon that plate I will illustrate by a line like that (*b*, *d*, see figure), showing increase in thickness at the lower edge of the glass plate. Both legs of this filament under these conditions with the interposed shield, remained perfectly clear and as brilliant as they were in the original lamp, although with increase of temperature the deposit of carbon on the bulb was materially increased. I then sealed into another bulb, without the glass shield, a series of platinum wires going all around it in the plane of the enclosed carbon, just little hooks, the wires passing through the bulb. I connected a telephone to the terminal which we will say was the positive pole. I connected the other terminal to loop No. 1, and with the lamp working at its normal candle-power, after I had obtained a certain degree of exhaustion, I succeeded in getting a musical note in the telephone. By then transferring the conductor to loop No. 2, I got a note of a slightly higher pitch, and upon transferring the connection to each succeeding loop, the pitch of the note correspondingly increased until I reached a point which was nearly diagonally opposite the stub + or in the line + 6, which would be the diagonal of the area enclosed by the loop, when I got the maximum note from the telephone.

"As I passed along up here (7—10) the note diminished in pitch until I got up here (10), when it was inaudible entirely. By connecting the telephone to the negative terminal and the sealed-in wires, I got no sound whatever. It was always a mystery to me and it is not yet solved, for the reason that I have been out of the incandescent lamp business for several years, and I would like to know whether any one else can explain the matter. As I understood Prof. Anthony in his paper to-night, he stated that the action which produced the blackening was not purely electrical, but was in all probability simply the volatilisation of the carbon alone at high temperatures. If a telephone was inserted between any two of these loops, I got no musical note whatever, indicating that there was no electrical action between those two points—no difference of potential sufficient to give a telephonic current. A peculiar feature about this experiment was this: that the lamp was on a direct current circuit, and the pulsation which would give that musical note must have been in all probability due to inequalities in the current of the dynamo. I used this dummy lamp as a means of indicating when I had secured the proper degree of rarefaction in the other lamps from the same pump. That is, this

lamp was attached to the same fork by which other lamps were being exhausted, and the exhaustion was continued until I got a slight note in the telephone, when I discontinued the exhaustion. These lamps, as they went out, had a residual atmosphere of chlorine gas, and possibly some little undecomposed chloroform which was subsequently decomposed in use. I made another preliminary experiment with a different construction, which was known as the U tube lamp. I believe it was subsequently patented by Mr. Stanley. In it I had a U loop of the same shape as shown in figure. The object of this construction was to protect each leg of the carbon filament from any direct electric action across from the other leg. This lamp was raised to a very high temperature without the filament changing its appearance, although the blackening of the bulb was very pronounced. I am very glad that Mr. Howell has brought some samples of lamps here to-night, showing the shadow cast by the carbon filament. I think any one who has had very much practical experience in the manufacture of lamps will be surprised to learn that carbon does not cast a shadow at all. It certainly was a very common thing in my experience to see lamps exhibiting this characteristic. I have succeeded in obtaining it with various lamps, and with platinum, iron and copper filaments, and I know no reason why, if the conditions are made proper, it may not be produced with all lamps. Of course, if the carbon is raised to a comparatively low temperature, and not subjected to sudden changes, the volatilisation will be very uniform and the shadow of the filaments will hardly be perceptible; whereas, if there are irregular or weak points in the filament or it is subjected to sudden changes in potential, then the shadows become quite marked."

Dr. Q. K. Bohm followed with some rather incoherent remarks connected with lamp blackening. Volatilisation was due, he thought, to the mechanical action of the current. The theory that carbonic oxide was formed and became decomposed on the glass he, very reasonably, did not believe. Bromine lamps, it was acknowledged, did not blacken. Why was this? "In my opinion it (carbon) combines chemically with the bromine, and such a combination does exist; it is tetra-bromine (bromide) of carbon. It is not black, and it may be in lamp globes in infinitely small quantities; but enough may be there to prevent the blackening." Combinations do take place in lamp bulbs; so if one chemical combination takes place, another can take place. "This will, in my opinion, reasonably explain the freedom from blackening of the bromine lamp." We give these latter views and quotations for the sake of the amusement they may afford to some readers, and will leave Dr. Bohm and Mr. Olan to settle between them what part chemical reactions and combinations play in the blackening or non-blackening phenomenon.

Prof. Anthony was brief in his reply, as the hour was late. With reference to Prof. E. Thomson's remarks on the softening of carbon by heat, he had not maintained the contrary, but agreed with him. He had only referred to the view that was sometimes erroneously put forward. Despretz had even welded rods of carbon more than 50 years ago. With reference to Mr. Howell's remarks, he was familiar with the fact that lamps sometimes improve in candle-power during the first 50 hours or so, but this was generally, if not always, accompanied by a decrease in resistance. In Table III. there was a decrease in the resistance in both vacuum and bromine lamps in 210 hours, and yet the former had fallen in candle-power. Mr. Howell had stated that the vacuum lamps he (the Professor) had used for comparison with the bromine lamps were poor lamps, but he would remind him that they were *all alike* up to the point of exhausting, and the tests show a remarkable difference in behaviour—and a very pertinent reply to the criticism this is. With regard to the remarkable life and candle-power test with vacuum lamps which Mr. Howell had described, all he could say was that he had never met with such lamps in commercial use. He was glad to find that the vaporisation of carbon theory had been generally accepted, though at the suit between the Edison and the Waring Companies it had been pronounced absurd. He could not agree, however, with Prof. Thomson and Dr. Böhm that the vapour would condense as soon as it left the region of the filament. This might be true if a gas were present to which it could give up its heat, but if the vacuum were perfect except the carbon vapour, to what would it give up its heat except to the walls of the vessel. [We think, however, the professor forgets how very little material is given off in a very extended period. The circumstance of the sharp phantom shadow seems to indicate that particles are shot at the glass, probably at such a velocity that they coalesce and thus form the film.] With reference to the view that gases in the chamber might serve as carriers of carbon, and thus cause blackening, he would call the attention of the gentleman who thought otherwise to the fact that the presence of *any* gas in the chamber in the proper quantity retards blackening.

Further written contributions to the discussion were sent in subsequent to the termination of the meeting, which were of an interesting nature, together with the regular discussion at Chicago, the more salient points of which we now give.

Prof. R. A. Fessenden did not agree with the view of thermal vaporisation as distinguished from the vaporisation produced by electrical means. He referred to an experiment, due, he thought, to Mr. Edison, in which a bundle of clean glass fibres are spread out like a broom and placed between the legs of a filament in a lamp, the plane of the broom being perpendicular to the plane of the filament. On running the lamp at normal voltage for a few hundred hours it will be noticed that the side of the broom next the + terminal will be perfectly clean to the eye, while the other side is covered with a thick black deposit of carbon. Had thermal vaporisation of carbon taken place, both sides would have been equally coated. He thought the phenomenon was due to a true Crookes effect, and that the decreased blackening in presence of a gas was due to the fact that it takes a greater potential to start a negative discharge into one gas from an electrode than into another; *e.g.*, it takes twice the potential to create a negative discharge from an iron electrode into nitrogen that it does to create a discharge from the same electrode in air. Phosphorous ought, if this view is correct, to give better results than chlorine or nitrogen, provided the vapour tension be sufficiently high.

Mr. C. J. Reed referred to the evaporation of metals that Prof. Anthony had spoken of, and mentioned that he had found that silver in a lamp would evaporate freely far below its melting point, and without the aid of an induction coil, a bright mirror being formed on the glass, which was blue by transmitted light. We may mention having had a similar experience with some special lamps of large candle-power, in which the filaments were supported on silver and gold wires. In the latter case the colour of the metallic film by transmitted light was a beautiful rose red. There was a great tendency in these lamps to short circuit across the terminals. That electrical action plays a material part in the blackening of vacuum lamps seems to us extremely probable. The argument advanced against the view that the blackening should be deeper in lamps of high than in those of low E.M.F. is not necessarily sound, as these experiences with silver and gold mirrors tend to show. The electrical currents detected in Mr. Colby's most significant and suggestive experiments may be at any potential, and they may very naturally play an important *rôle* in projecting the molecules of carbon vapour as it forms against the glass.

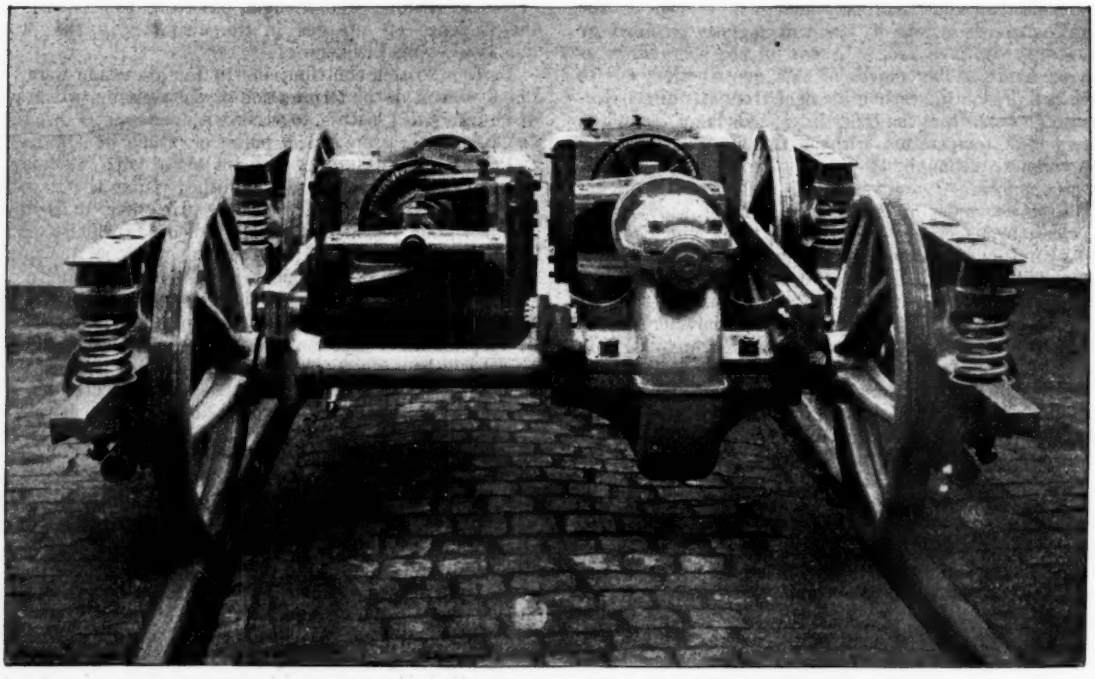
TESTS OF RECKENZAUN TRAMWAY MOTORS AND GEARING.

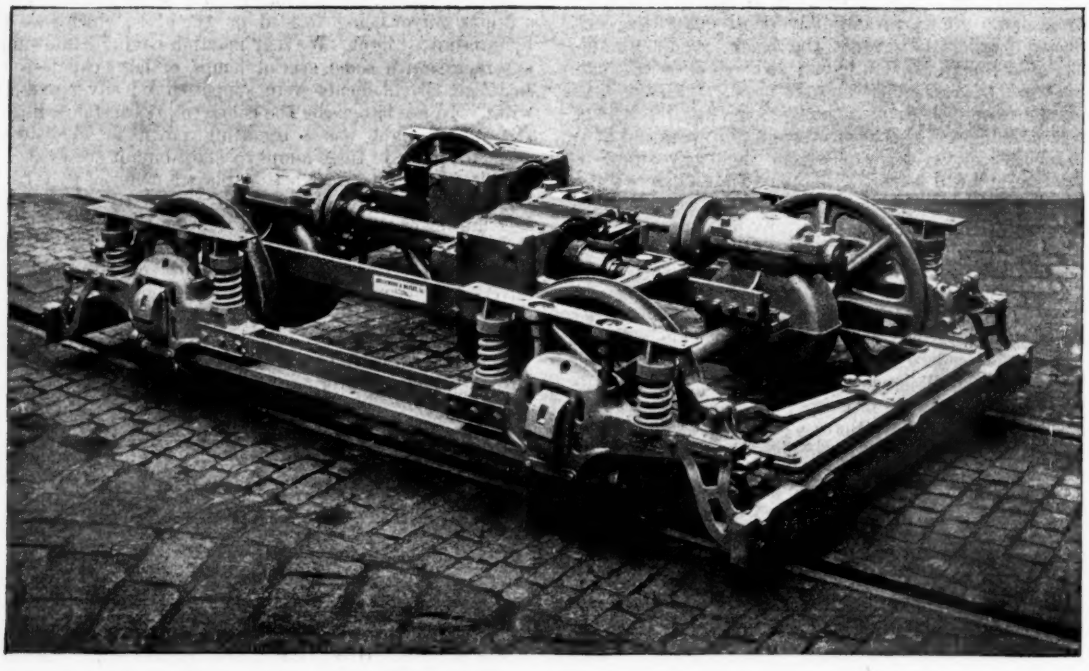
By PHILIP DAWSON, A.M.Inst.C.E., A.I.E.E.

During the past year an experimental electric tramway, with overhead conductors, has been in operation at the Leeds works of Messrs. Greenwood & Batley, Limited. The motors are from the design of the late Anthony Reckenzaun, Esq., and the system of worm gearing employed to transmit power from the motor to axle is that which he so long and earnestly advocated. The following notes of a series of efficiency tests, made upon a double motor truck, may interest many who read the long series of articles from his pen which have appeared in these columns.

Motors and gearing are mounted on a special truck, the exterior framework of which is supported by the steel castings in which the axle boxes are contained, and upon which rest the spiral springs to carry the car body.

The weight of motors and gear is supported by an interior frame, weighing 9 cwt., and bearing directly on self-lubricating boxes on the car axles. Wheels and axles are of cast steel, and powerful brake gear grips all four wheels. Diameter of wheels, 30 inches; weight of truck alone, 16 cwt. 2 qrs.;





weight of motors, gear and interior framework, 1 ton 13 cwt. 2 qrs.

The motors are series wound, and nominally 10 H.P. each. The magnet frames are of wrought iron and the pole-pieces of cast iron, the armatures are Gramme. The resistance of the field magnet pieces is 0·456 ohms, and of the armature 0·244 ohms. Normal revolutions per minute, 800. Carbon brushes are used with the best results, no wear of commutators being discernible.

The gearing is of especially careful construction. The worm is turned out of a solid piece of steel and well polished, diameter 6 inches, and has a treble thread of 6 inches pitch. The worm wheel is of phosphor bronze, 15¼ inches diameter, and has 24 teeth thoroughly trimmed. The whole is enclosed in a cast-iron casing which is thoroughly dust and waterproof. This casing is also used as an oil well, to ensure continuous and automatic lubrication. It will be seen by the above dimensions that the inclination of the worm thread on the spindle is 45°. This is the angle which gives the highest

efficiency. If we neglect the velocity with which a point of the worm displaces itself along its axis and the friction of the bearings, we find :—in calling a the angle made by the worm with its spindle, ϕ the angle of repose of metal on metal, and η the efficiency,

$$\eta = \frac{tg\ a}{tg\ (a + \varphi)},$$

and differentiating with regard to a, and equalling to zero, we find that the maximum efficiency is obtained for

$$a = \frac{\pi}{4} - \frac{\phi}{2},$$

or as ϕ is always very small

$$a = 45°.$$

If we take the exact formula, giving the theoretical efficiency of the above gear

$$\eta = \frac{1 - \mu \frac{p}{2\pi r}}{1 + \mu \frac{2\pi r}{p}}$$

η, efficiency,
μ, coefficient of friction,
r, radius of the worm,
p, divided axial pitch,

and apply to the present case, taking $\mu = 0{\cdot}15$ as given by Prof. Unwin in his "Elements of Machine Design," we get as the theoretical efficiency only 66 per cent.; whereas, carefully conducted brake tests show actual efficiencies of from 84 to 95 per cent.

The following are results of actual brake tests made by the late Mr. A. Reckenzaun :—

Efficiency of gearing ...	84·3%	89·6%	91·6%	95·4%
Revs. per minute of the worm wheel	38	84	96	112
Linear velocity, in feet per minute ...	152	336	384	448
H.P. transmitted ...	0·985	2·31	2·23	1·64
Thrust on tooth, in lbs. ...	248	263	199	132

The high efficiencies obtained in these tests are due to the careful design of the worm gear and of the two metals used, phosphor bronze and steel, the co-efficient of friction between which is very low, as well as to the careful cutting and polishing of the teeth, and abundant lubrication.

Instead of taking $\mu = 0{\cdot}15$, it should be taken as 0·003 and less. The experiments of Wm. Sellers, published in *Engineering* in the first half of 1886, are most interesting in conjunction with the preceding tests, some of his results are given below :—

Angle of axis of worm to plane of thread.	No. of threads on worm.	No. of revolutions per minute.	Efficiency in %.
5°	1	200	75
10	1	200	86
15	2	200	90
20	3	200	92
30	4	200	95
45	6	200	96½

From what has been said it will appear that for worm gearing to be efficient a high peripheral speed, a limited pressure between the teeth, an angle of worm axis and plane of thread as near 45 degrees as possible, and a multiple thread, is necessary.

The gearing of the experimental car at Leeds was not as carefully finished as might have been wished. It is wonderful what a difference carefully polished teeth and worm make in the efficiency of this kind of gearing. The author, wishing to get a rough idea of the combined efficiency of motor and gearing, without taking the car to pieces, jacked the truck up, so that the motors could easily revolve; connected the wheels of the car by two leather belts, and then using one of the motors to drive the other as a dynamo (the field of the driven motor being in series with the fields of the driving motor), measured the electrical input and output, regulating the current of the driven machine by means of carbon resistances.

The following results were thus obtained :—

Revolutions of motor per minute.	Input in watts.	Output in watts.	Efficiency of motor and gear combined.
300	3,200	6,850	$\frac{\sqrt{0{\cdot}467}}{0{\cdot}93}$ 73 %
500	1,570	3,520	$\frac{\sqrt{0{\cdot}446}}{0{\cdot}93}$ 72 %
640	2,350	5,500	$\frac{\sqrt{0{\cdot}427}}{0{\cdot}93}$ 70 %

Then supposing the average efficiency of the motor to be 83 per cent., this gives for the efficiency of the worm gear 84 to 88 per cent., which is in accordance with what previous tests of this kind of gear would have led one to suppose. In the above rough and ready tests, the loss due to the stiffness of the belts as well as to the friction of the car axles in their journals, has been estimated at 7 per cent., which is not too high considering that the belts were new and very stiff and narrow, besides which they had to be very tight, and even then the slipping was considerable.

Some of the severest strains to which motor and gear were put, were during a long series of tests made to ascertain the shortest interval in which the car could be stopped when going at its highest speed. These tests were carried out on an incline of about 1 in 40, the loaded car being run down at the rate of 22 miles an hour. The current was then suddenly reversed, and the car brought to a standstill within 30 yards without the use of the brakes.

When the current is cut off, the car runs on with the greatest ease, the worm-wheel driving the worm without any appreciable loss in friction. On the level, one man could push the loaded car, running against the worm. The smoothness of running and starting is remarkable, and the gear is quite noiseless. These characteristics, as well as the large speed reducing power, 1 to 8 (or about twice that of single spur gearing), enabling cheaper and lighter motors to be used, were some of the many advantages claimed by Mr. Reckenzaun for this gearing.

The system of speed regulation is as follows :—

The field of each motor is wound with two separate coils, and by means of a barrel switch the motors and field-magnet coils may be placed in the following four positions, the resistance of the motor circuit varying with each :—

(1.) Motors and field-magnet coils in series.
(2.) Motors in series, field-magnet coils in parallel.
(3.) Motors in parallel, field-magnet coils in series.
(4.) Motors and field-magnet coils in parallel.

This arrangement allows all speed and power regulation required; and very strong initial torque (or statical pull) being secured at starting. Reversal is effected by means of the barrel switch, consequently, no accidental or injurious reversal is possible, as the motors must necessarily be cut-out before their direction is changed.

The gradients and curves on the experimental line are most unfavourable, the way very rough, with numerous points and crossings. The length of the line is about 800 yards.

In tramway work, it is very important that the efficiency of the motors should remain high through a large range of output, as the work required of the motor is very variable. As is seen from the following tests made with a Prony brake this has been remarkably well obtained in the case of these motors.

The magnet coils of the motors being only in series at starting, the low efficiency is then of little importance, and it will be seen that between 3 and 8 H.P., which is the normal output, the efficiency is extremely high. The great and sudden variations of speed in electric traction are illustrated by the following ampère curves.

The instruments used in the tests were "Goolden" marine volt and ammeters, with special damping arrangement. A Schaffer & Budenberg speed indicator was geared by means of a belt to the worm spindle.

The first diagram applies to a run of 1,600 yards with one stop and reversal. The mean current (exclusive of the single stoppage) would be 46 ampères, and the mean speed 8½ miles per hour. Notwithstanding the damping arrangement, the

Magnet Coils in Series.

Ampères.	Revolutions per minute.	Effective H.P.	Commercial efficiency in per cent.	Torque in foot pounds.
14	0	...	...	13
31	0	...	...	32
50	0	...	...	56
57	0	...	...	64
25	692	3·3	67	...
36	538	4·3	64	...
48	475	5·5	62	...
	Magnet Coils in Parallel.			
20	950	3·26	84	...
33	1,010	5·78	84½	...
38	765	5·82	82	...
47	880	7·80	82¼	...
50	680	7·80	...	...
60	770	8·80	76	...
72	700	10·10	76	...

sudden variations caused the needle of the ammeter to swing violently, and to show a greater current on the instrument than was really passing.

It will be observed that when changing from one position of the switch to another there is a very marked drop in the current; this is due in the present case to the graduating resistances introduced between the different positions of the switch being too great. Between two and three this drop is remarkably low; in fact, the ammeter (placed between the fields and the armatures), ought to indicate no current, both armatures being simultaneously short-circuited when passing from series into parallel. In a new design for the switch this has been done away with, one armature at a time being short-circuited.

The great fall of potential is not due to the resistance of the line nor to the shunt dynamo used as generator, but to the steam engine which did not govern well, and was not strong enough for the work required of it.

The ammeter indicates the slightest curves or gradients occurring on the line, and every unevenness in the road has its counterpart in a rise of current. Only, unless the ammeter used is extremely dead-beat sensitive, the rise in current may be very difficult to register accurately. The second diagram represents results obtained on a run of 1,600 yards, including five stoppages on curve and grade. The average speed is about 4·6 miles per hour, the mean electrical H.P. furnished to the car 5·65, and the mean current 43·5 ampères. In all these tests the average voltage was, approximately, 160 volts, or about half the voltage used on trolley lines in England.

These diagrams* show the great and sudden fluctuations of current and power required in driving tramcars, and the consequent sudden strains to which the machinery at the generating station is constantly put. The conditions under which an electric railway power station has to be designed are obviously entirely different from those governing the planning of a lighting station.

TESTING FOR GROUNDS ON INCANDESCENT CIRCUITS.†

By AUSTIN S. O. LATCH.

After reading Mr. G. L. Thayer's article on "Grounds on Incandescent Circuits," in the *Engineer*, of April 11th, I send you a method I have used for about five years and think it will commend itself to your readers, as no lights are disconnected in locating the ground. With slight modifications, the system can be adapted to alternating, as well as direct current, and either isolated or central stations. I devised the method from some experiments made by Mr. M. M. Waddell, of the Waddell-Entz Company, and myself, at the Edison station, in Detroit, in our attempt to locate grounds on the underground system by other than the "cut and dry" method.

The mechanical stokers in that station are run by a small engine, with the ordinary ball governor. We used this governor to interrupt the current from a bank of lamps, as shown in fig. 1. An iron arm is fastened to the governor

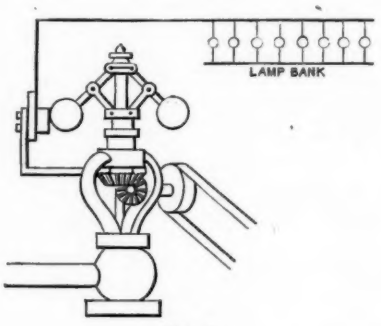


Fig. 1.

frame; this carries a block of wood, on which is a metal strip. The governor balls strike this strip and thus complete the circuit to ground through the engine. This gave an interrupted current through the system, from the ground to the station, and by carrying an induction coil with a telephone receiver over the wires, we were able to follow in the direction of the ground.

My method is a modification of this. I divide the system into sections and with auxiliary bus bars can test each section without putting out the lights. After locating the section, I would try the inside wiring with the device shown in fig. 2. This consists of an induction coil with a receiver

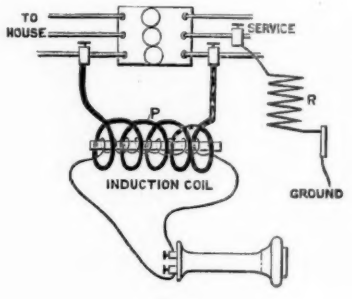


Fig. 2.

connected to the fine wire terminals and a non-inductive resistance with an interrupter. The primary of the induction coil has screw clamps for terminals so that it can be connected to each side of the cut-out. The resistance coil, R′, is connected from the other wire to ground. By removing the plug or fuse strip the current will pass through the induction coil. If the ground is in the building there will be a heavy induced current in the receiver; otherwise, only a slight hum caused by the direct current. If the ground is in the building a few more such tests will easily locate the ground. Should the ground be found on the outside underground wiring, it can be located without danger of producing fire; so putting on a load at the station the indicators will show which feeder it is near. A junction box can now be opened, knowing that not more than one other will need be.

The first thing I do after opening the box is to test the feeder for ground, disconnecting of course. If it is in the feeder, I disconnect both in the station and junction box; then connecting the terminals together in the junction box, I measure by the ordinary sliding bridge method, as shown in fig. 3. This is simply a Wheatstone bridge, and the point in the wire loop where the galvanometer is connected when the needle comes to rest, will divide the loop just as the ground divides the feeder.

* We cannot reproduce these elaborate diagrams as the reduction to suit our pages would render them almost, if not quite, useless.—Eds. Elec. Rev.

† New York *Electrical Engineer*.

Should the ground be in the mains, I use the same method as in inside testing, only using a heavier interrupted current, since the ordinary current is heavier. After locating the main and disconnecting so that it feeds from one end only, I put as heavy current through the ground as is safe without burning the smallest service, should the ground be in it. I now measure the voltage across this load and simultaneously at the services. The voltage across the load will be the

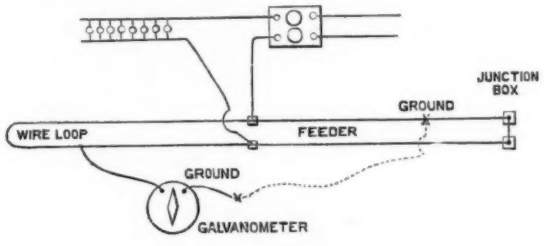


Fig. 3.

same as that of the two services on each side of the ground. This is shown in fig. 4. A, B, C, D, E, F, are services; the voltage at M across the resistance is the same as at F, and possibly a little less than at E, since the current in passing through to the ground and back to K will produce an appreciable drop in the wire from K to the ground; but the services, F, G, H, will remain the same as M, as the testing is made when the load is light.

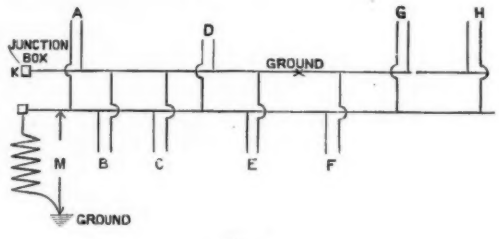


Fig. 4.

With the induction method 5 ampères is a large current, and usually 2 or 3 is enough, depending on the normal current in the line. If the ground be in a cord or fixture, this current will blow the fuse without any danger of fire. I do not advise a lamp bank for a testing resistance, as it will attract attention, while a non-inductive resistance coil will give the appearance of connecting a telephone on the line "to hear the flow of the current." With overhead lines only the inside tests need be made, as a good inspector usually knows his faulty spots and where to look first.

This may seem to be a long, roundabout method if the cut and dry method has been used. But usually with two men, and often only one, I can locate the ground as soon as two men will by the "guessing process." Even if it took twice as long or cost twice as much, I would still advise the above method. I believe too much emphasis cannot be put on the importance of uninterrupted service either isolated or central station. One disconnected service costs ten times the apparent saving even if disconnected only for a moment, and it may cost a good customer. I believe the principal cause for the opinion of instability in electric lighting is due to the habit of employés indiscriminately disconnecting customers for testing purposes.

Of course we are avoiding grounds now by our better methods of wiring, both inside and out, than were employed five, or even three years ago; still we have them and that shows we cannot be too particular in watching our insulation resistance records. On arc circuits, Rudd's method is the best; but for Edison, or other multiple arc systems, I think a modification of Mance's method for measuring a resistance containing a potential difference or else using two voltmeters at once is to be preferred. I do not think much of measuring the resistance when the wires are idle, but want the condenser effect.

THOUGHTS ON COSMICAL ELECTRICITY.*†

By ELIHU THOMSON.

Having been requested to speak to the Electrical Section of the Institute on some subject, it occurred to me that I might take the opportunity to present a few thoughts in the nature of speculations on the electrical relations of the earth and the heavenly bodies.

Where we have no definite knowledge we are forced to speculation, and often scientific speculation points the way to further advances in our theories. While speculation is not science, science is often benefited by speculative ideas; speculation is the result of imagination, science of investigation.

We know but little as yet regarding the actual facts in the study of cosmical electricity. We do know, however, that there is every reason to believe in the existence of electrical disturbances in space, and either proceeding from or concentrated by the bodies in the solar system.

We have, indeed, much to learn, and the difficulty of learning is the greater as we are called upon, in this case, to apply known principles to conditions comparatively unknown and difficult of conception by our mental powers. As an illustration, I may mention the paradox of the canals of Mars. Of all the planets, Mars is the one which appears to be like the earth, and, therefore, is the one, the phenomena of whose surface, it would seem, should yield most readily to interpretation. But we are puzzled at the very outset. So, also, it must be with a subject such as I have chosen for my talk to-night.

It is known that as we leave the surface of the earth and rise in the air, there is an increase of positive potential with respect to ground, such that on the top of the Washington Monument it may be 3,000 to 4,000 volts, and on the Eiffel Tower as much as 10,000 volts. On high mountains similar high potential differences are found. If the increase were equal to 1,000 volts for each 100 feet on the average, it would equal, at 20 miles altitude, about 1,000,000 volts, and from this it might be inferred that the conducting vacuous layer of rarefied air at great altitudes would possess a very considerable positive potential with respect to ground.

But just here we are confronted with a difficulty. It is not clearly proven that a pure gas, rarefied or not, can receive and convey a charge—solid or liquefied particles in it might readily do so, but there are considerations which seem to negative any assumption that gas molecules can themselves be charged.

If we imagine a charged drop of water suspended in air and evaporating, it follows that, unless the charge be carried off in the vapour, the potential of the drop would rise steadily as its surface diminished and would become infinite as the drop disappeared, unless the charge were dissipated before the complete drying up of the drop by dispersion of the drop itself, or conveyance of electricity by its vapour. The charge would certainly require to pass somewhere and might leave the air and vapour charged. However this may be, the vacuum outside of our atmosphere is probably perfect, and, therefore, a perfect insulator. The ether itself appears to be the best insulator, or most nearly perfect non-conductor of electricity.

It is customary to speak of a charged body—this metal ball insulated in air, for example—as a thing by itself, but we well know that its capacity to receive a charge depends on the thickness of the surrounding dielectric, or the nearness of other conducting surfaces, such as the walls of the room, the floor and ceiling and other objects about it. The insulated ball is none the less one of the coatings of a condenser, the capacity of which depends on the thickness of the dielectric layer separating it from those objects or surfaces which form virtually the other coating.

It is doubtful then if a single body, in unlimited space, would be able to receive a charge of electricity, and it follows that even very large bodies like the earth and stars, separated as they are from one another by immense distances, cannot have much capacity. A comparatively small amount of electricity would give a very high potential in such a case.

* A lecture delivered before the Electrical Section of the Franklin Institute, December 19th, 1893.

† This lecture formed the subject of some comments in our issue for January 26th, 1894.

It becomes an interesting question, just here, whether the fact that a charge resides only on the surface of a charged sphere or conductor, is due to attraction of opposite charges of sphere and surrounding objects, or to repulsion of like charge in the sphere, or to both. A simple consideration will show, I think, that it is due to both causes, and that lines of electrostatic induction joining oppositely charged surfaces and traversing the dielectric between them, are like lines of magnetic force, in that they both tend to spread laterally and also to shorten their paths. Their actual course, as is the case with the lines of magnetic force, will be determined by the resulting balance between both tendencies. Thus in fig. 1, if two opposed surfaces, A, B, are charged

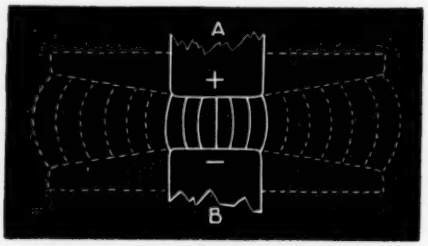


Fig. 1.

relatively, and then the surfaces be extended laterally, as indicated by dotted lines, and the extensions be of receding character, as shown, the charge will distribute itself over the added surfaces by virtue of the lateral spreading of the lines, while in doing this the actual length of the lines is increased.

Now, returning to the case of the earth, its capacity as a body insulated in space could not be very great, and a moderate amount of electricity in coulombs would give it a high potential. Viewed in another way, however, the earth may possess a much greater charge, or amount, of electricity. The solid earth itself is a conductor, the dense air around it a good insulator and dielectric layer, the rarefied air above a quasi-conductor in the sense that it can at small potential differences distribute a charge or convey a current, and the ether outside is a perfect insulator.

The earth may then possess the character of a huge conductor, the outer coating being rarefied conducting air, the inner coating, the ground and water surface and the dielectric the dense air between. The outer layers may possess a potential, positive with respect to the earth's body, of perhaps, as much as 1,000,000 volts.

Prof. H. A. Rowland has shown, however, that a moving charge is equivalent in magnetic effects to an electric current representing a similar transfer of electricity, and that a rotating charged air condenser produces that magnetic field which would be due to a current going in the direction of the moving changes on each plate. Applying this to the earth considered as a huge revolving condenser, fig. 2, the dense air layer, A, A, would become magnetised from pole to pole, and the velocity of the equatorial portion being so much greater than that of portions near the pole, would allow the magnetic lines to dip on each side of the equator in short-circuiting themselves through the solid earth, E.

Moreover, the magnetic field so produced does actually correspond in direction of polarisation with that which would be given when the outer coating, V, V, is positive to the inner E, thus confirming so far the hypothesis which I have ventured to present to your consideration. It is merely a thought and would need comparison of many data to give it a secure basis as a theory.

Any action which would disturb the charge of the condenser earth, would strongly affect the earth's magnetism, and auroras especially would do so. They appear to represent a distribution of charge in the outer layers of the earth's atmosphere.

Assuming the earth to be a huge charged condenser, a thunder-storm might be brought about by a flow in the dense air dielectric, due to the presence of clouds of condensed vapour, extending to great altitudes. They may be the auroral actions repeated in denser air, giving spark discharges, where in the aurora the diffused vacuum discharge only is seen.

The enormously high potentials exhibited in the thunder-storm may be secondary effects, due to coalescence of many minute drops of water charged to only moderate potentials, the reduction of surface raising the potential. It may in part be due also to evaporation of charged drops in some parts of the cloud, again reducing the surface and raising the potential.

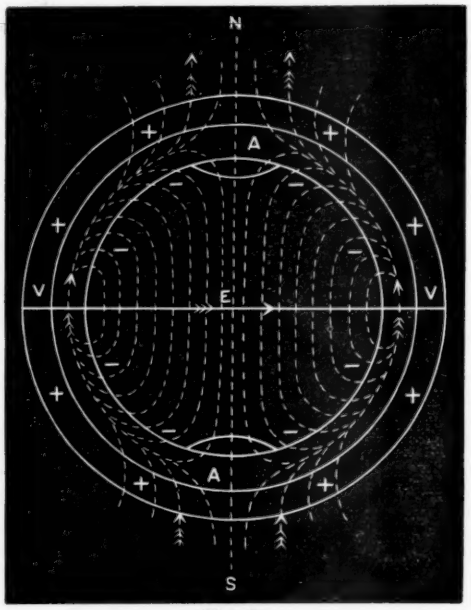


Fig. 2.

The electrostatic induction of innumerable drops in a cloud, each drop possessing a like charge, gives virtually the effect of the possession by the cloud, considered as a whole, of a very much higher potential than is possessed by a single drop.

There must be some influence constantly at work to cause and maintain the positive potential of the higher layers of the atmosphere, for otherwise in various ways there would naturally be brought about an equalisation of the charges of air and earth. Many theories have been proposed to account for the positive electrification of the air in its upper layers, and it may be that the condition is the result of a combination of causes rather than of any single cause. It is a legitimate thought, it appears to me, that the electrification may in large measure be due to influences outside of the earth itself. Let us assume a vast nebulous mass as having been the origin of the solar system by cooling and condensation, according to the nebular theory, and if for any reason that nebulous mass have a small charge or be at a potential difference with respect to other gaseous masses in space, the diminution of surface during shrinkage would gradually increase the potential of the charge, provided it could not escape through the surrounding ether. This charge would increase in potential until the finer particles on the outside of the mass were repelled outwards with a force equal to their centripetal tendency or gravity. A dispersion of such particles would ensue, and result in a fall of potential. The dispersion and accumulation of charges would occur periodically, while the hot mass of gas was shrinking and the particles sent off would be condensed vapours, liquid or solid, forming a charged cosmic dust proceeding in a radial direction from the central mass, just as the carbon sent out from a filament of an incandescent lamp leaves the filament radially after having condensed from vapour to solid carbon immediately at the surface of the filament, owing to the instant loss of the heat necessary to keep it vaporous.

Now the distance between the sun and a planet, such as the earth, is so great, that it is not probable that any considerable static-inductional effect could exist between them, even if they were at great differences of potential. On the other hand, electrified particles repelled periodically from the sun would reach the earth's atmosphere. It has been suggested that the coronal streams seen during total eclipses, particularly during the active or sun-spot period, may consist of electrified particles leaving the sun. If so, their lack of visibility, beyond a few diameters from the sun, would not

forbid the assumption being entertained as a rational one, that the streams may pass outward indefinitely until they encounter some obstacle like the earth. But auroral displays on the earth are frequent only when the solar activity is greatest, when the coronal streams extend outwardly the farthest, and there appears to be a distinct connection between the presence of large spots on the sun's surface and auroral disturbances here.

Can we not consider that during an aurora the earth is passing through a coronal stream and developing, as it were, a secondary aurora, either by directly encountering in space the electrified particles from the sun, or by induction from streams of such particles near the earth's course?

Taking these thoughts in connection with the idea of the cause of the earth's magnetism presented above, it will be easy to understand why magnetic disturbances should be prominent during auroras. Taking also the fact that the sun is a charged body, and probably the planets also, it will be understood that some influence on the earth's condenser charge would exist, varying according to the positions relatively occupied by these bodies, and particularly of earth and sun. This, in turn, would give rise to magnetic variations, such as the diurnal, annual and secular variations. It would account for the fact that the diurnal variations are greater when the earth is nearer the sun than when more remote.

My thought then, is, that the sun may be a charged body insulated in space, and, that owing either to a periodical accumulation of charge up to a certain critical potential, which would repel the outer particles into space and so relieve itself, or, to thermal disturbances occurring periodically during the cooling, the sun-spot period, or active period, recurs every eleven years, deforms the sun's outline, so far as the outer atmosphere is concerned, and raises the potential or the projecting parts to a degree to cause repulsion of particles; continuing until a certain discharge is effected, after which there is quiescence again.

During these actions the earth passes through, or near to, electrified streams and an aurora, or earth corona, is developed.

Concerning auroras, it would appear from observations of the great displays, that the crown or corona, seen in the zenith, is merely a view of bundles of streamers *on end*, and that the streamers in the north while nearly radial to the earth, are seen in perspective, rapidly changing their shapes and positions, while to the east and west are seen as comparatively stable but lest defined streamers—an average view of great masses extending hundreds of miles and made up of innumerable changing streams of which the luminous effect is nearly steady. The grandest aurora which ever came under my personal observation was that of April, 1883, which reached its maximum between 12 and 1 o'clock. The whole horizon was in view as I was on top of a hill, and it is no exaggeration to say that the whole sky from north to south horizon and from east to west, was filled with auroral streams of wonderful colouring. The crown in the zenith was a marvellous display of changing light, changing positions, changing intensity and changing colour. The streamers in the north were sharply defined like great bundles of luminous needles and seemed almost within reach. They changed rapidly, were remarkably brilliant and covered an angle from about 20° altitude almost to the zenith. The stars, even of the first magnitude, could scarcely be seen, and although there was no moon, the time could easily be read on a watch, and the roofs of buildings, ten miles away, could easily be distinguished. I mention this aurora particularly because it showed in a most striking way the characteristics stated above, as indicating the radial position of the streamers. On no other theory could the zenith crown and streamers be seen simultaneously at places hundreds of miles east and west and many miles north and present substantially the same appearance.

It would appear that auroral displays are either much more rare in the southern hemisphere or absent altogether. Speaking on the subject with Dr. Gould, of Harvard University, he informed me that, although he had lived in Chili for fifteen years and was constantly on the watch for auroras, he never in that time saw a single display.

Now, if a discharge is taking place under critical conditions in a high vacuum, the relation of its path and direction to a magnetic field in the vacuum may determine the continuance or cause a stoppage of the discharge, according to the direction of magnetic polarisation. Or, a stream of electrified particles may be deflected by a magnet, as shown in the well-known Crookes tubes. From this it might follow that the magnetism of the earth may be inhibitory to the discharge in the southern hemisphere and favourable to it in the northern, in which case the relatively greater frequency of the aurora *borealis* would be explained.

It has been found as a result of recent investigations that a negatively charged body will, if exposed to violet light, dissipate its charge to surrounding bodies, probably by sending off atoms, molecules or particles of its own substance negatively charged.

A positively electrified body placed in the neighbourhood of a body maintained at a negative potential under violet light, is soon discharged by the negatively electrified particles coming to it from the negative body even when the positively charged body is not in the light. Whether this dissipation of negative charges would take place in the ether itself, or in a very high vacuum, is, so far as I am now aware, not known. Evidently, however, such an action would have a very marked influence on the retention and distribution of charges on the earth.

If the sun's charge be positive and positively electrified particles are sent out in the coronal streams, it would be easy to understand that the outer earth charge might be kept up from the sun and that not only auroras, but thunderstorms also would be more frequent during periods of solar activity. Observations tend, I think, to show that such is the case.

Again, if the sun be a highly electrified body, might it not be possible that cometary masses may owe some of their illumination to redistribution of electricity as they approach towards and recede from the sun, or to encounter with electrified particles leaving the sun? Here, again, the radial direction of the comet's tail is suggestive, as are also the rapid changes which the comet undergoes.

And lastly, as a concluding thought, we may ask whether the phenomena of the sudden appearance of a star, which, after reaching great brilliancy, fades out in a few days or weeks, may not be referred to electrical causes, such as the equalisation of charges on near approach of two bodies, attended as it must be with an enormous evolution of light, gradually fading away as the vapours cool after the discharge. Thus, some of the temporary stars may possibly be explained.

In conclusion, I beg to remind you what I have offered you here are only thoughts, not theories—which a careful comparison of all the facts may serve to confirm or to discredit. Objections may arise, but oftentimes what seems an insuperable objection disappears in the light of more complete knowledge and observation. It is true that the thoughts presented are not all new, and it is only the more gratifying when others may have arrived at similar guesses. Though generally busy with the practical side of electrical science, it is a source of pleasure sometimes to let one's thoughts have full play, even if the result be only a maze of speculation, some part of which may prove to be fallacious.

CORRESPONDENCE.

The Leonard Method of Motor Regulation.

In your issue of April 20th, Mr. A. G. Seaman, speaking of my method of motor regulation, says: "Theoretically it is almost perfect; it promises high efficiency, perfect ease of control, saving in stopping, &c. The difficulty is to find the generator. It is easy enough to design a dynamo which at full excitation will have practically no armature reaction, but I have never yet come across one which was capable of supplying its full working current at $\frac{1}{10}$th its normal voltage without sparking badly. It would be interesting if Mr. Leonard would tell us whether he had found this difficulty, and if so how he has got over it."

Mr. Seaman's statement must be based upon some false theory and not on practice, for although I have my method in successful commercial operation on no less than ten different types of generators made in the United States, I have never met with the slightest tendency of sparking on any one of them under the conditions of use in my method,

where double the full working armature current is often supplied by an armature at $\frac{1}{20}$th of its normal voltage.

Mr. Seaman is in good company as regards his error as to the sparking of a generator under these conditions, for many of the most eminent electricians of the United States, and at least two in your country have stated unequivocally that a generator must spark under these conditions, but no amount of expert opinions can alter the actual fact that it does not spark. Furthermore, there is, I think, no reason to expect sparking. The conclusion that a generator will spark when producing large armature current in a weak field seems to be based upon its supposed analogy to the case of a shunt motor connected to a constant E.M.F. circuit and having a large armature current in a weak field. The cases are, in fact, entirely different.

In the case of a shunt motor the ratio of the total E.M.F. on the commutator to the number of commutator bars remains constant when the field is weakened. In the case of a generator, however, this ratio which is the chief factor in the tendency of sparking in a well designed machine, is reduced in direct proportion to the weakening of the field, and the increased tendency to sparking due to the distortion of the neutral line by the armature reaction is perfectly balanced by the reduced tendency to sparking due to reduction of the "volts per bar," and there is no sparking whatever, nor is any adjustment of the brushes required even when the field is reversed.

In the discussion of my paper, "How shall we operate an Electric Railway Extending One Hundred Miles from the Power Station," before the American Institute of Electrical Engineers, February 21st, 1894, this question was thoroughly ventilated, and I should be glad to furnish a copy of the paper and its discussion to any one interested.

H. Ward Leonard.

Personal.

My attention has been called to a paragraph in your edition of 20th ult. headed "Personal," stating that Mr. R. H. Drummond has been appointed chief electrician of the electric light station of this company at Madrid.

I have to inform you that Mr. Drummond's appointment is that of *assistant* electrician, Mr. J. W. Chisholm, who has held the post of chief electrician for the last 12 months, continuing in that position.

I beg you will be good enough to correct the statement in your next number.

P. A. Latham,

Secretary Electricity Supply Company for Spain, Limited.

Mr. Crompton's Paper.

In common with Mr. Raworth and very many others, I value greatly the papers and speeches of Mr. Crompton, who always deals with topics of the largest interest in a lucid and thoroughly practical manner. Therefore, I am a little sorry to find your correspondent, Mr. Booth, coming down so heavily upon him with regard to his remarks about Lancashire boilers, before the conclusion of the paper had been published—though my own personal feelings run in the same direction as Mr. Booth's, who never writes without having something of consequence to say.

He will have seen Mr. Crompton's modification of the opinion at first expressed in his paper, and the object of this letter is to ask your correspondent whether he would tell us through the medium of the REVIEW, if his position is, that considering the variable and exceptional nature of central station work, a Lancashire boiler with flue economiser, fired with north country coal, should be more economical than a water-tube boiler, such as the Babcock? If this is not his position, then, valuable as Mr. Booth's article is, I do not think it materially affects Mr. Crompton's conclusions. But I fancy he means us to understand that he adopts this view. Of course it is different to that held by many leading electrical engineers, but Mr. Booth may truly say in answer to that, that these have still something to learn about boilers and steam raising. I think a great many of your readers, besides myself, would feel grateful to Mr. Booth if he would take up this question in another article and justify his position, supposing that I have correctly defined it. The advantages of Lancashire boilers are such that most engineers would like to use them if they could, but Mr. Booth does not need me to remind him that running a central station and a Lancashire cotton mill are two very different things. I hope he will be disposed to say something further on this matter.

Howard Tozer.

May 14th, 1894.

Electricity Meters.

In Mr. R. P. Wilson's letter in yours of May 11th, he proposes to vindicate his own historical accuracy at the expense of my veracity, by publishing a copy of a letter of his own sent to me; but what earthly connection his accuracy, my veracity, and that letter can have in the way he proposes to use it I cannot conceive. I need not characterise that letter, it speaks for itself.

I think I have already vindicated my claim to the priority of invention in dispute, and I am prepared to still further vindicate my claims at the expense of your correspondent's historical accuracy, veracity, and logic; all three seem to be faulty.

Rankin Kennedy.

May 12th, 1894.

Self-Lubricating Bearings.

I am sorry I had not noticed the remarks of Mr. R. A. Goodman on this subject, in your issue of the 4th, earlier.

It is quite true that this bearing is in use in the mills of Messrs. B. Vickerman & Sons, Limited. It is equally true, I believe, that it has run for many years without any cost of renewal. It is also true that this bearing, which they have in use, was invented by their then engineer, Mr. W. H. Broughton (a marine engineer), who made his experiments and developments privately, with an understanding between the late Mr. Vickerman and himself, that anything he did should not prejudice the action for a patent. It was not made public property in any sense, nor has it been made public property, and I can only say in conclusion, by way of assurance, to Mr. Goodman, that his remarks have only increased my enthusiasm and confidence—if it were needed—in what is a *bonâ fide* "improvement and invention," and one that is and will continue to be a paying investment. I need not ask for a better testimony of this than his own notes.

William Farrar.

P.S.—In your first article on this, Perseverance Works should have read Providence Works.

"Porous Lithanode."

Glancing hurriedly through the present issue of the ELECTRICAL REVIEW, your heading, "Porous Lithanode," and the familiar name of Mr. Desmond G. FitzGerald caught my eye at once. Lithanode is a special pet of mine. I immediately turned to the Abstract of Patent, No. 4,691, 1893, in your issue of May 4th, 1894, and there find a description of a process very well known and practised by us years ago. As works manager and electrician, I made many batteries of the porous lithanode for the Primary Battery Company, Limited. Being now away from my test books, I cannot refer to my dates, &c., nevertheless I am under the impression that even in 1884 these were being made. However, that is not a matter of much importance, but to your readers it may be useful to know that there is no novelty in this process as there would appear to be by the publication of the abstract, No. 4,691. Besides employing in the manufacture of lithanode an inert material or salt such as the sulphate of magnesia, which will afterwards be removed or dissolved out, we used other salts which were more suitable for the purpose of producing any degree of porosity throughout the material, or for surface porosity.

It was while Mr. Kingsland and I were working upon Mr. FitzGerald's patents that we found it expedient to name the

child. As sponsors we suggested "Petranode," but the parent objected, and he substituted "Lithanode"—of course, a more correct and scholarly coinage. This child had the novelty of standing alone without a conducting support even from infancy, and of adapting itself to any form, either slab, tile, or mass, in fact a regular little brick.

I am rather digressing, but I merely mention this in support of Mr. FitzGerald's correspondence, and to bear testimony to the fact that those who were connected with the manufacture of lithanode from its incipiency were also quite familiar with this method of producing surface porosity.

W. Howard Tasker.

May 15th, 1894.

THE PACIFIC CABLE QUESTION.

Sir John Pender has addressed the following letter, dated May 15th, to Sir Charles Tupper, and has also sent a copy to the *Times*:—

"I have carefully looked through the paper which you read last week at the meeting of the Royal Colonial Institute, and had I been well enough to attend the meeting I should have made an effort to be present. I cannot, however, allow your statement to pass unchallenged that the 'protest against the proposed cable is largely based upon fallacies,' feeling convinced that if you would carefully study our figures and arguments, which are based on actual facts and practical experience of cable working, and compare them with those furnished by Mr. Sandford Fleming, you would come to the conclusion that the fallacies are not on our side, but on your own. For instance, to take the first point in your paper relating to amortisation, you are entirely mistaken in stating that 'some 5,350 miles (or about 30 per cent.) of the 18,000 miles of cable now forming the system of the Eastern Extension Telegraph Company is more than 20 years old, and is still in working condition, the balance of about 12,650 miles being duplications and extensions laid since 1874.' As a matter of fact, nearly the whole of the cables originally laid by the Eastern Extension Company have been renewed, some entirely, and in a considerably shorter period than 20 years. Then, as to your estimate of traffic for a Pacific cable, you have quite ignored the fact that at the Wellington Conference it was decided that the ordinary tariff should be 3s. per word, instead of 3s. 3d. as proposed by Mr. Sandford Fleming; consequently, after the necessary out-payments are deducted, which would probably amount to 1s. 6d. (1s. for the Atlantic cables and 6d. for the Canadian and Australian land lines), there would be only 1s. 6d. left for the Pacific cable instead of the 2s. relied upon by Mr. Sandford Fleming, and this discrepancy materially affects your figures. Moreover, any calculations based upon such an unknown quantity as the 'normal increase of traffic' cannot be at all reliable, as the circumstances are constantly changing. For example, the growth of traffic with Australasia during the year ending April 30th, 1892, was only 8·34 per cent. over that of the previous year, and in the following year, ending April, 1893, it was less than 6 per cent. as compared with 1892, showing that Mr. Sandford Fleming's estimate of a *minimum* 12½ per cent. is quite misleading. It is equally unsafe to rely too closely on calculations of increase resulting from reductions of tariff, experience having unfortunately shown that on more than one occasion a falling off of traffic has actually taken place after a substantial lowering of rates, instead of a considerable increase, such as your paper indicates would result if the Australian tariff were reduced from 4s. 9d. to 3s. 3d. were word. Then, again, your description of the existing system as a 'monopoly' cannot be justified, seeing that it has never received any exclusive landing rights from the Australian Governments, but has had to rely upon the business-like and economical principles upon which it has been established and worked for its freedom from competition. In fact the field has always been open to all comers to compete with us, and upon equal terms I should have nothing to say against it, but supported by Government aid it would be quite another matter, and if a Pacific cable were established on this basis and the pioneer company, which has done so much for the Australasian colonies in providing them with perhaps the best submarine service in the world, were ignored, it would certainly be disastrous to private enterprise, and the Governments interested could not in common fairness adopt such a course without granting similar pecuniary assistance to the existing system. No doubt a single cable could be constructed and laid for £1,800,000, and it would undoubtedly materially benefit the cable manufacturers, but no company who knew anything about the business and would be held responsible for carrying it through could undertake the work with any prospect of making it pay on the terms of the Wellington Conference resolution. At the present moment, however, the proposed cable is not really needed for commercial purposes, and therefore the expenditure of nearly two millions sterling, when neither the Imperial nor Colonial Governments can well afford it, would, in my opinion, be an unwarrantable waste of money. If, however, the Governments concerned consider a second cable is required for strategic purposes, which I very much doubt, they must, of course, pay for it, and, as I have frequently stated, my company would be quite prepared to undertake the work on fair and reasonable terms, which terms would necessarily be more favourable to the Governments than could be obtained from any other company, owing to the exceptional facilities possessed by the existing system. The probability of opposition arising from foreign sources does not in the least alarm me, but should competition be brought about through English and colonial agencies on the proposed terms, the result must inevitably be that no dividend would be forthcoming for the new company, and little, if any, for the pioneer service. I have thought it only fair to yourself, as well as to the companies which I represent, that you should be placed in possession of the above information, as you will doubtless be making further reference to the Pacific cable movement, and with so much attention now being paid to all public utterances on the subject, it is of the greatest importance that all figures bearing on the question should be as accurately stated as possible."

BUSINESS NOTICES, &c.

Electric Lighting and Transmission of Power.—Recently Messrs. John Davis & Son, of Derby, have carried out a large number of lighting, pumping, and hauling contracts at various collieries, in addition to a number of mills, factories, shops, and complete plants for country residences. The following may be mentioned: A combined lighting and haulage plant erected for the West Hallam Colliery Company, near Derby; colliery pumping plant for the Ackton Hall Colliery Company, near Pontefract. This latter plant was an emergency one, and was started to work by Messrs. Davis within 10 days of receipt of order. A combined lighting and pumping plant with a motor constructed under the Davis & Stokes patent has been erected for the Clay Cross Company at their Morton Colliery. Another extensive pumping plant with spare power for lighting, for the Wingerworth Colliery Company, near Chesterfield, for clearing the flooded workings, is now situated one mile from the dynamo, and is forcing 12,000 gallons per hour up a vertical height of 150 feet, through 2,400 feet of 2-inch pipe. In order to deal with the water quicker, a duplicate plant is now being constructed to deliver its water on the surface. They have supplied for abroad to the St. John Del Rey Gold Mining Company, plant for lighting their stamp mills, shops, yards, mines, &c., with arc and incandescent lamps. A large lighting and power plant for Messrs. F. Longdon and Co.'s mills in Derby has also been supplied by them, the number of lamps being over 500, of candle-powers varying from 8 C.P. to 32 C.P. Messrs. Davis are also engaged upon several complete plants for country residences.

Asylum Electric Lighting.—The Northumberland County Asylum gas plant having worn out, the County Council have been considering what steps to take in the matter of renewal. The county architect has reported upon the estimated total cost of carrying out the recommendations as to the gas works. The county architect's estimate of the cost of gas works was £3,930, to which should be added, for the purpose of comparing it with the estimated cost of electric lighting, £1,130 for steam power required for new laundry with boiler, boiler house, and chimney, which are included in estimated cost of electric lighting, making the total cost for gas works and new boilers £5,060. As the cost of gas was so much, the committee deemed it advisable to consider the question of electric lighting, and, by their direction, Mr. W. C. Mountain, of Newcastle, examined the asylum and gas works and made a report. The estimated cost is £5,350, including two high pressure boilers, which would provide steam for the new laundry and for heating, and would cost, as stated by the county architect, £1,130; but to this £5,350 was to be added foundations for boilers, renewal only of present gas works, and new boilerhouse, &c., as stated in the architect's report, making the cost £7,010, and for specifications and supervision of works during construction by an electrical engineer, £265, making the total cost, £7,275. The committee after going into the whole matter, were in favour of adopting the electric light, and recommended it for the approval of the County Council.

The Derby Electrical Exhibition.—The electrical exhibition at Derby, to which we have already referred, was opened on Monday afternoon. It is being held under the direction of the Electric Lighting Committee of the Town Council. The catalogue of the exhibition is a nicely prepared and bulky pamphlet. It contains briefly the history of the electric light movement in Derby, also a description of the central station, details of the exhibits of the thirteen electrical firms having stands at the exhibition, as follows:—Messrs. The Electrical Company, Limited, W. T. Glover & Co., Pyke, Harris & Co., Limited, C. A. Parsons & Co., Crompton & Co. (cooking by electricity, demonstrated by lectures, &c.), W. T. Henley's Telegraph Co., Limited; the latest Edison phonograph exhibit by Messrs. Wyndham & Seward, F. & C. Osler, the General Electric Company, Limited, Edison & Swan United Electric Light Company, John Davis & Co., Siemens Bros. & Co., Limited, Henry Baker. The Electric Lighting Committee seem to have gone in for a thoroughly good local exhibition, which should have effectual influence upon the minds of the inhabitants of the district of supply, and induce them to take up the light.

Church Lighting.—St. Bride's Church, Kelvinside, Glasgow, is to be lighted with electric light. The supply will be taken from the mains of the Kelvinside Electricity Company. This is the first church in the district to be lighted with electricity; the plans and specifications were drawn out by Mr. W. Elsdon Dew, resident engineer to the supply company, and the contract has been placed in the hands of Messrs. Claud Hamilton, Limited, Glasgow. Other churches in the district have been considering the advisability of likewise keeping up with the times.

The Fire at Dublin.—The Superintendent of the Dublin Corporation supply station has written to the *Irish Independent*, contradicting a statement which had been circulated that the private electric lighting supply in the city was affected by the fire, to which we referred last week: "No interruption of any sort took place in the private lighting, in fact it was kept on longer than usual at the special request of the Hotel Métropole. The only interruption that occurred was to one circuit (out of three) of the street lighting, when the arc lamp was smashed by the front wall falling, and this was remedied as soon as it was safe to approach the ruins. At 2 p.m. on Friday, owing to the burning gas escaping from a broken gas service to Arnott's in close proximity to our mains, it was deemed advisable to disconnect the supply to three consumers in Mary street for a time. This was simply a precautionary measure until the pipe could be disconnected by the gas company's men, and the possible danger removed. The general supply was perfect, as it always has been, and was in no way affected by the fire in the building. The main switch controlling the lights in Messrs. Arnott and Company's premises was turned off on the night of the fire, so that the premises were completely isolated from our mains."

Theatre Electric Lighting.—With reference to our notice under this heading last week, a correspondent writes: "I notice in your issue of the 11th you mention Messrs. Vaughan & Brown, of Kirby Street, London, as being responsible for the lighting of the Empire Palace Theatre, Birmingham. As this will naturally lead your readers to suppose that this firm has carried out the electric lighting, I will be obliged if you will kindly state the facts in your next issue, which are these: The electric lighting of the whole building has been carried out by the Manchester Edison-Swan Company, Limited, the plant consisting of a Frickers patent tubular vertical boiler capable of supplying steam for a Marshall engine developing 60 brake horse-power, driving a "Lancashire" dynamo, having an output of 360 ampères at 105 volts at 660 revolutions per minute. The machine is of the drum armature type having Lowmoor iron magnets. The total load when all lamps are on is equal to 600 16-C.P. lamps, and includes the whole lighting of the theatre inside and outside, with the exception of some gas lighting on the stage, a sunlight for ventilating purposes, and some burners in passages, &c., for use when the plant is not running. The gas lighting only has been carried out by Messrs. Vaughan & Brown.

Cheltenham Electric Lighting.—The Borough Surveyor has been authorised to secure assistance in the electric light department to help him in the superintendence of the laying of the cable and other works, the assistant to hold office until the appointment of a permanent officer. Applications are invited for the post of electrician for the borough at a commencing salary of £200 per annum, such salary rising by annual increments of £10 to £250. A specimen of tube proposed to be used in carrying the electric cables, and which had been approved by the Board of Trade, having been submitted, the Surveyor has been authorised to obtain 15,000 yards thereof, at 35s. 5d. per 100 feet, from Mr. W. C. Hawtayne, of Victoria Street, S.W. He was also directed to proceed with the laying of the conduits as soon as the tubes are ready. Tenders for the required cables have been ordered to be advertised for in the electric light papers, and for the buildings in two local papers.

Electric Light for Ayr.—The Town Council of Ayr on Monday night had again under consideration the question of adopting the electric light in Ayr, and of themselves proceeding with the introduction under a provisional order obtained some years ago, or handing their rights over to a private company, and the result is that they definitely agreed to proceed with the installation without the intervention of private enterprise. A very elaborate report by Mr. Hammond, electrical engineer, and also an offer by the Caledonian Electric Supply Company, Edinburgh, to take over the powers of the Council, were submitted. It was agreed to authorise Mr. Hammond to proceed with the preliminary work, and the arrangements were remitted to the Lighting Committee. The first cost of the works has been estimated at £15,000.

Coventry and the Electric Light.—The application of the corporation to borrow £20,000 for the purpose of electric lighting was last week the subject of a Local Government Board inquiry. A site for the station has now been acquired on the Foleshill side of the city, near canal and railway, by which means coal can be easily conveyed to the works. The engineering works tender amounts to £9,672, and it is intended to put down two engines sufficient to supply 5,000 incandescent lights. There is no intention at present to light the Coventry streets with electricity, and little local demand for the light has been shown, but it was said by the consulting engineer to be the experience elsewhere that supply created a demand.

Electric Light in the Covent Garden District.—The Strand District Board have referred to the Works Committee an application of the secretary of the Charing Cross and Strand Electricity Supply Corporation for the board's sanction and approval, and a provisional order from the Board of Trade, so as to enable the corporation to supply electric energy for arc and incandescent lighting and motive power purposes within the parish of St. Paul's, Covent Garden.

Wolverhampton and Electric Lighting.—The Lighting Committee of the Town Council intend to recommend the acceptance of the tender of Messrs. Bailey, Pegg & Co., of Brierley Hill, for the supply of 36 arc lamp posts at £5 15s. each, and five arc lamp brackets at £2 15s. each.

Eastern Telegraph Company, Limited.—This company announce that code restrictions for all the offices in Brazil have been withdrawn.

Personal.—We understand that Mr. E. R. Dolby, C.E., of 8, Princes Street, Westminster, S.W., has been appointed consulting engineer to Messrs. C. H. Glover & Co., Hatcham Saw Mills, for electric power transmission plant and electric crane; to the London Missionary Society for electric lighting; and to a colliery in Derbyshire for lighting, transmission of power, and pumping by electricity.

Church Lighting.—Messrs. Rashleigh Phipps & Co. have received instructions from the Marylebone Presbyterian Church, Upper George Street, Edgware Road, to instal an additional 200 lights in the church. This is the second order placed in the hands of this firm, who lighted the vestries and committee rooms in the Autumn of last year.

Barking and Electric Lighting.—The Local Board has at present under consideration the question of electric lighting. New public offices are being erected, and the question whether these offices should be lighted by gas or by electricity has been some weeks under discussion.

West Ham and Electric Lighting.—The Town Council have resolved that tenders be forthwith invited for lighting the Public Hall and Public Library, and the lamps in front thereof by electricity by means of an installation worked from the Public Hall premises.

Electric Lamp Pillars.—Messrs. Geo. Smith & Co., of the Sun Foundry, Glasgow, through their London house, have been entrusted with a large order for electric lamp pillars by the Great Northern Railway Company, for the lighting of their various goods yards and stations.

Blackpool Electric Lighting.—The Town Council have been recommended by the Electric Light and Tramways Committee to obtain five street transformers complete, and that Mr. Hammond, the consulting engineer, be authorised to order the necessary low tension mains at a cost not exceeding £800, including laying.

Change of Address.—Messrs. King & Co. inform us that they have removed to new business premises, and their address is now Leith Electric Works, Prince Regent Street, Leith. The new premises are situated in close proximity to both the North British and the Caledonian Railway Stations, and to the docks.

Derry Electric Lighting.—In the estimates passed by the Corporation last week was an item of £2,479 for electric lighting and gas during the summer half-year of 1893, compared with £1,100 as the estimated cost for gas alone.

Club Lighting.—D. & G. Graham, of Glasgow, have secured the contract for the electric lighting of the new Conservative Club, Bothwell Street, Glasgow. The specification for the electric lighting was prepared by Mr. T. Ekin, A.I.E.E., London.

Greenock Town Hall Lighting.—A sub-committee has been appointed to consider a better method of lighting the Town Hall. Electric wiring and other contractors should be on the alert here and get electric lighting introduced.

Electric Light for Dunoon.—The Burgh Commissioners are at present contemplating the introduction of the electric light into the Castle Gardens this summer. The estimated cost is between £400 and £500.

Theatre Lighting.—The new Theatre Royal, Aston, has been lately altered and the electric lighting arrangements entirely overhauled and improved.

Lighting of St. Pancras Baths.—The Baths Commissioners have been requested by the Vestry to consider the question of lighting the baths by electricity.

CONTRACTS OPEN AND CLOSED.

OPEN.

Fleetwood (Lancs.)—May 19th.—Buildings.—For erection of new buildings in the town's yard, London Street, Fleetwood, for electric lighting station, and also for the erection of underground transformer chambers in streets, for the Fleetwood Improvement Commissioners. Plans of the proposed works may be inspected upon application to the surveyor, Mr. M. S. Gaulter, from whom copies of the specifications and form of tender may also be obtained.

CLOSED.

Bootle.—The Town Council last week resolved that the tender of Messrs. W. and J. Robinson & Co., for the supply and erection of the electric light installation in the Town Hall, Municipal Offices, Free Public Library and Museum, Magistrates' Courts and Offices, Police Buildings, and Public Baths, in accordance with the specification prepared by Mr. T. L. Miller, and approved by the committee (exclusive of the supply of fittings) for the sum of £3,224 be accepted subject to Messrs. W. and J. Robinson & Co. entering into the necessary formal agreement for the execution of the work. Mr. Miller is to be employed to superintend the installation.

Worcester.—On the recommendation of Mr. W. H. Preece, to which we referred in our last issue, the City Council have accepted the tender of the Brush Electrical Engineering Company to

lay the necessary mains for fixing 26 15-ampère alternate current arc lamps in High Street, the Cross, the Foregate, Foregate Street, St. Swithin Street, Mealcheapen Street, and Broad Street, and the necessary lamp posts, lamps, &c. (such lamp posts to be of a pattern to be selected by the Watch Sub-Committee), at the price of £1,861, subject to the Local Government Board sanctioning the requisite loan, and to the company agreeing to carry out the work as an extra, on the terms of their present electric lighting contract.

BOOKS RECEIVED.

Mr. Martin's Law Suit. Reprint, slightly condensed, from the *Electrical World.*

The Physical Review. May-June, 1894. Published for Cornell University by Messrs. Macmillan & Co., of New York and London.

The Practical Management of Dynamos and Motors. By FRANCIS B. CROCKER and SCHUYLER S. WHEELER, D.Sc. Second Edition. Published by D. Van Nostrand Company, New York, and E. and F. N. Spon, 125, Strand, London, W.C.

Continuous Current Dynamos, their Theory, Design, and Testing. An elementary treatise for students. By FRANK B. COX, B.S. Published by the W. J. Johnston Company, Limited, 41, Park Row, New York.

Electric Transmission of Intelligence and Other Advanced Primers of Electricity. By E. J. HOUSTON, A.M. Published by the W. J. Johnston Company, Limited, as above, and Messrs. Whittaker and Co., Paternoster Square, London, E.C.

Electrical Measurements and Other Advanced Primers of Electricity. By E. J. HOUSTON, A.M. Published by the W. J. Johnston Company, and Messrs. Whittaker & Co., as above.

Electricity and Magnetism. By E. J. HOUSTON, A.M. Published by Messrs. Whittaker & Co., as above.

Alternating Currents: an Analytical and Graphical Treatment for Students and Engineers. By F. BEDELL and A. C. CREHORE. Second Edition. Published by Messrs. Whittaker & Co., and the W. J. Johnston Company, as above.

NOTES.

The Institution of Electrical Engineers.—On Thursday, May 24th, at 8 p.m., there will be the continuation of discussion on Mr. Crompton's paper on "Cost of Electrical Energy."

Fire.—The enormous fire which raged at Brooklyn the other day, destroying Dr. Talmage's famous Tabernacle and an approximate hotel, is stated to have been caused by the electric wires connected with the organ coming into contact. The loss through the fire is at least $1,000,000.

Bury Electric Lighting.—Subject to the approval of Dr. Hopkinson, plans, specifications, and estimates for the proposed electric lighting station have been passed by the Council. Tenders are shortly to be obtained, and application is to be made to the Local Government Board for power to borrow £25,000 for the electric lighting work.

Brighouse and Electric Lighting.—The Council was petitioned the other day to sanction an application being made by private individuals for a provisional order. Sanction has been withheld at present, and we believe the Council intends discussing, sooner or later, the advisability of keeping the supply under its own direct control.

Buxton and Electric Lighting.—Electric lighting has seemingly been blocked at the discussion stage, and will proceed no further yet awhile, at any rate, if the Local Board are allowed to adhere to their decision of last week. Three members voted for the appointment of an electrical engineer and five against. One member went so far as to suggest waiting until the year 1902—8 years!—before undertaking the supply, as they are heavily laden with loans at present. We do not presume to prophesy, but we would warn the Local Board that unless Buxton inhabitants are less pushing than the ratepayers of other provincial districts, private enterprise will have taken up the work long before 1902, and the Local Board will not find it so easy after all.

The Lighting of the City.—The electric lighting of the City streets has lately caused a good deal of additional interest to be taken in it lately, on account of certain statements made by Mr. W. H. Preece and others as to the comparative costs, to the City authorities, of the present and the past systems of public lighting. The great increase has astounded not a few. The attention the matter is at present receiving has called forth a very interesting letter from Mr. H. H. Bridgman, who is a Commissioner of Sewers as well as being a member of the St. Pancras Vestry. He is therefore in a position to compare the respective costs, &c., of the lighting of the two districts. The letter, which appeared in last Saturday's *City Press*, we consider worth reproducing in full:—

A contemporary has called attention to a statement by Mr. Preece, the electrical adviser to the Commission, wherein he is represented as saying that the electric lighting in the City costs £27 per lamp, whilst in St. Pancras the cost is only £17 per lamp, and suggests by way of explanation that the City should have undertaken its own electric lighting the same as St. Pancras did, instead of allowing contractors to do it, and so reap all the benefit. I have not read the actual statement said to have been made by Mr. Preece, but, as I consider him to be as discreet and accurate as he is capable as an electrician, I feel satisfied he would not have given utterance to such an expression without duly qualifying the same. In the first place the contract price of the City lamps is not £27, but £26 each per annum, and the answer to the alleged statement as to the difference of cost per lamp will give a very different complexion to the subject; but for the fact, however, of the City electric light contractors having the private lighting of the City as well, the cost would not be so low as £26 per lamp. I happen to be a member of the St. Pancras Vestry as well as a Commissioner of Sewers, and I very much question the accuracy of the price named per lamp in St. Pancras. I have not the reports by me, but my impression is that the cost is very considerably higher than £17 per lamp. The figures given, however, are sufficient for my present purpose, as I may have to return to the subject again. In St. Pancras 86 arc lamps displaced 479 gas lamps. In the City 479 arcs displaced 1,258 gas lamps, or in other words, each arc lamp in St. Pancras displaced 5½ gas lamps, whilst in the City each arc displaced only 2⅝ gas lamps. This means that practically in the City the arcs are only half the distance apart that they are in St. Pancras. If, therefore, the number of lamps in St. Pancras were doubled, the cost of lighting would practically be doubled. The lamps I should say are the same nominal power, viz., 2,000 candles, both in the City and St. Pancras, whilst the distance between the gas lamps was about the same. Now a simple calculation will show that, distance for distance, the St. Pancras arc lamps compared with those of the City ought only to cost £13 per annum each, whereas £17 per lamp shows an excess in cost of 31 per cent. on the cost of the City lamps. I do not write with the slightest thought of disparaging St. Pancras. On the contrary, I think it says much for the pluck of the vestry that they should be the first of the metropolitan parishes to embark in so bold an enterprise as to light the streets by their own installation; but personally I have always considered in this matter of electric lighting that it is rather beyond the province of the local authorities to risk the ratepayers' money in enterprises which must be largely experimental, whilst there are so many public companies with private funds at their back to compete for the work of developing the principle of electric lighting. Monopolies are not created thereby, because there is ample provision made by Act of Parliament enabling local authorities to buy up the electric light companies on fair and equitable terms if purchase should be deemed desirable. This option is very important to public authorities. The public and private lighting of the City by electricity is a great work, and, including the cost of the sites of the generating stations, has involved an expenditure of very nearly a million capital (£972,000). This includes the erection of buildings, the equipment of the three stations, and the distribution, and provides for 515 arc and 906 glow lamps of 200 watts each for the public lighting of the streets, as provided for in the contract with the Commissioners of Sewers, as well as for equipping the stations and providing plant for the supply and conversion of current for private lighting in accordance with detailed specifications and schedules of prices approved by the Commission, necessitating an output of 1,000 kilowatts for public and other arc lighting, and 12,100 for private lighting—in all 13,100 kilowatts; and the cost has worked out at £75 per kilowatt. The carrying out of the work, with the exception of the delay and inconvenience occasioned chiefly by the laying of the mains in such crowded thoroughfares in the City has been, on the whole, considering the enormous amount of work done, very satisfactory; and this satisfaction, so far as the public lighting is concerned, is emphasised by the fact that the gas lamps are now being removed from all the main thoroughfares. The public lighting is practically perfect, the failures, if they can be so called, being infinitesimal, and, in my humble opinion, taken as a whole, the action of the Commissioners of Sewers throughout has been so sensible and businesslike, that if the entire business had to be now begun I do not see how they could much improve on the lines they have followed. The delay in the carrying out of the private lighting has been also, to a large extent, consequent on the difficulties of obtaining sites for the numerous transforming stations for regulating the supply, of which there are, I think, 42 equally distributed over the City, being in nearly every instance placed underground, involving necessarily great expense in construction and elaborate fitting. Now that the work is practically completed, I think the City may be congratulated that it has been entrusted to such an enterprising and energetic company.

Electrotropism.—The fact that certain animals living in water are affected in their position and in the direction of their movements by a constant electric current, has been known for some time, but no one has until now ventured upon an hypothesis to explain it. The subject has recently been seriously investigated by E. Blasius and F. Sweizer, who have collected a large number of observations upon animals permanently or occasionally inhabiting water concerning this phenomenon of electrotropism. The experiments were made with a current of 108 volts from the Berlin Electrical Works, and showed that when the head of a fish, for example, is directed towards the anode, calmness or even stupefaction is occasioned, whilst when the fish occupies the opposite position, excitement is occasioned, and is accompanied by effort on the part of the fish to escape the stimulating effect, and participate in the tranquilising effect of the current. It would appear, therefore, that the phenomena of electrotropism would proceed from the effect of the current upon the nerves of sensation, and there would ensue, according to Pflüger's well-known law of electrotonus, a decrease of excitability at the positive, and an increase at the negative pole. Amonst other curious observations it was noticed that fishes, if transversely traversed by the current, display a behaviour analogous to the symptoms of dizziness, which occur in man on transverse galvanisation of the head, as they always sank on the side turned towards the anode. By comparative work with an accumulator current at 77·6 volts, it was ascertained that this current was just like a dynamo current in its effects.

The City and Guilds of London Institute.—The Annual Report of the Governors of this Institute, which has just been issued, shows that there has been a steady increase of the number of students attending the Central Technical College, the number for 1892-93 having been 205, as against 184 for 1891-92. The distribution of students who pursue a complete course of instruction is as follows:—Civil and Mechanical Engineering, 70; Electrical Engineering and Physics, 93; Applied Chemistry, 10. The total number of day students at the Technical College, Finsbury, for 1892-93, was 213, as against 198 in 1891-92. The number of Electrical Students was 106, the Mechanical Department having 66, and the Chemical, 41. The Evening Department had 168 in the Electrical Department out of a total of 359. The Technological Examinations continue to be increasingly popular, the total number of students who were examined having been (for the year) 25,653. In Telegraphy and Telephony the number of candidates has increased from 209 to 240, and the percentage of failures from 48·3 to 50·0. In the ordinary grade the percentage of failures has risen from 53·9 to 65·7, and in the honours grade from 26·4 to 30·0. With reference to the large number of failures in the ordinary grade, the Examiner reports that "the candidates have shown a lamentable ignorance of principles which are clearly explained in almost every standard text-book." In the section of Telephony alone, which is a branch of the honours grade of the joint subject, the number of candidates has increased from 3 to 12, and the papers were of sufficient merit to justify the award of two prizes. In Electric Lighting 439 candidates were examined, and the percentage of failures has increased from 62·4 to 64·9. Copies of the Examiner's report on this subject have been sent to the several centres where candidates were examined. In the quality of the answers in the honours grade a very decided improvement is reported to have taken place, but judging from the recurrence of the same mistake in large batches of papers, the Examiners are of opinion that "in certain centres the teaching is in the hands of persons who have no real acquaintance with electrical engineering." In Electro-Metallurgy the papers in the ordinary grade are described as "very good, even those who failed showing the results of good teaching." The Examiner states, however, that "the honours papers are less good, and that none of them show a clear knowledge of the principles of Electrolysis."

New Engineering Laboratory.—The new Cambridge Engineering Laboratory was opened on Tuesday last by Lord Kelvin, in the presence of a good many officials of the University, and Sir F. Bramwell, &c.

Windsor and Eton Electric Lighting.—The Windsor and Eton Local Boards have each appointed deputations to jointly consider the question of electric lighting.

Obituary.—The death of Mr. Arthur Edward Robinson, head chemist at the Electric Construction Works, Bushbury, took place at his residence the other day after a brief illness.

Hertford and Electric Lighting.—A committee are considering the question, and are obtaining particulars as to the expense of the installation and probable number of consumers.

Ealing Electric Lighting.—The price to be charged for current for private lighting is 6d. per unit. The electric lamp pillars are to be fixed in the middle of the Uxbridge Road.

Reductions in Price per Unit.—The Kensington and Knightsbridge Electric Lighting Company, Limited, have resolved that after the 1st of July current supplied by them will be charged for at the standard rate of 6d. per Board of Trade unit, instead of 8d., as previously.

The Westminster Electric Supply Corporation has decided, after Midsummer next, to reduce the price of electric energy for motive, cooking, and heating power purposes to 4d. per unit, where the supply is taken through a separate meter.

Morecambe Electric Lighting.—The alleged nuisance caused by the central station here, to which we have already referred, was the subject for discussion at the last meeting of the Local Board. After lengthily considering the matter, it was resolved that the surveyor, medical officer, and Mr. Preece (of Andrews and Preece) be instructed to visit the works, with a view to suggesting some means whereby the nuisance could be stopped.

Whitehaven Electric Lighting.—The figures just published regarding the cost of electric lighting for the year 1892, compared with the cost of gas lighting during the previous year, show up very satisfactorily. The public *gas* lighting for 1892 cost about £884; the public *electric* lighting for 1893 cost £1,080, less £207 revenue collected, leaving £873, which is about £11 or £12 the cheaper of the two years. This is very different to the comparative costs of the London public lighting.

The "Intelligent Workman."—On Monday night, May 7th, there was a considerable failure of the public arc lamps (Brush system) in the Western District of the City of London. In all 36 lamps failed to light up, these being the lamps on one side of New Bridge Street, Ludgate Hill, Fleet Street, Farringdon Street, &c. The cause of the failure was the short-circuiting in the Queen Victoria Street subway of the conductors on the concentric main from the generating station at Bankside, and forming part of the circuit serving these lamps. This short-circuiting was caused by a pin driven into the cable through the wires of the outside conductor and reaching to the centre. The pin had been inserted by one of the Electric Lighting Company's employés in the subway. This man had also inserted a second pin in another concentric cable running alongside. His desire was to light a glow lamp by connecting it across the two conductors. He had probably seen the same thing done before with the low tension distributing mains. As he failed to secure this result, or indeed any result at all, for the mains were dead at the time, he apparently was a little frightened, and left the spot after withdrawing the pin from one of the cables. The fault was not easy to localise, and current was not sent through the lamps until close upon dawn on the 8th.

NEW COMPANIES REGISTERED.

Electric Motive Power Company, Limited (41,132).—This company was registered on the 10th inst. with a capital of £20,000, in £1 shares, to carry on the business, patents, &c., comprised in, and for that purpose to execute,

a certain agreement intended to be made between E. J. Clubbe and A. W. Southey, and to carry on the business of electricians, electrical engineers, and mechanicians. The subscribers (with one share each) are:—Gordon Cox, Salter's Hall Court, E.C., solicitor; D. G. Fitzgerald, 94, Loughboro' Road, S.W., electrician; C. T. J. Oppermann, 2, Wynyatt Street, E.C., electrical engineer; G. B. Hilliard, Florence Road, Ealing, W., gentleman; E. J. Clubbe, Viewsley, Uxbridge, electrical engineer; A. W. Southey, Rosenthal, Dacres Road, S.E., electrical engineer. There are not to be fewer than two nor more than six directors; qualification, the fact of being a shareholder; remuneration to be determined in general meeting. Registered office, 3, Salter's Hall Court, E.C.

Wilkes Contract Company, Limited (41,143).—This company was registered on the 11th inst. with a capital of £5,000, in £1 shares, to contract, execute, repair, and maintain in any part of the world, railways, harbours, docks, water and gas works, telegraphs, electric works, or works for the supply or application of electricity, and to carry on the business of manufacturers and dealers in metallic or other patent paving. The subscribers (with one share each) are: W. Farrels, 56, Cannon Street, E.C., engineer; A. East, 92, Doggett Road, S.E., solicitor's clerk; F. N. B. Wrighton, 73, Basinghall Street, E.C., solicitor; D. Walker, 13, Sise Lane, E.C., gentleman; H. A. Wilkes, 23, Martin's Lane, E.C., clerk; W. Ulrid, 179, Shaftesbury Avenue, E.C., clerk; F. Overton, 99, Upper Addiscombe Road, Croydon, civil engineer. Table A mainly applies. Registered by Joseph B. Roberts, 78, Basinghall Street, E.C., solicitor.

British Aluminium Company, Limited (41,104).—This company was registered on the 7th inst. with a capital of £100,000, in £10 shares, to acquire any mineral clays and other substances suitable for the production or manufacture of aluminium, sodium, iron, or other metals, and to carry on the business of the production, use, and sale of electricity and electric power, including lighting by electricity. The subscribers (with one share each) are:—C. F. Jones, The Maples, Gleneagle Road, S.W., gentleman; N. Pettimalti, Earl's Court, S.W., clerk; R. Widenham, 116, Percy Road, W., agent; J. W. Chew, 7, Victoria Street, S.W., secretary; C. W. Jones, 32, Great George Street, S.W., surveyor; V. Lambley, Fulham, clerk; A. R. H. Belcher, 21, Borringdon Road, S.W., gentleman; T. West, 18, Rodney Terrace, Putney, S.W., gentleman. The number of directors is never to exceed nine; qualification, £200; remuneration, £1,000 per annum, divisible. Registered by Wilson, Bristows and Carpmael, 1, Copthall Buildings, E.C.

Immisch Electric Launch Company, Limited (41,118).—This company was registered on the 9th inst. with a capital of £12,000 in £1 shares, to acquire from the General Electric Power and Traction Company, Limited, their electric launches, charging stations, lease of Platt's Eyot, and generally the goodwill and business of the Thames Launch Department of the said company; to enter into an agreement for this purpose; and to carry on the business of electricians, manufacturers and dealers in launches, &c. The subscribers (with one share each) are:—M. Immisch, 48, Tollington Park, N., electrical engineer; L. Alwyn, 49, Queen Victoria Street, E.C., electrical engineer; H. Gardner, Queen Street Chambers, E.C., electrical engineer; W. Bullock, 4, Warwick Villas, N., accountant; S. Sillon, Cromwell House, Gresham Road, Staines, civil engineer; H. Twelvetrees, The Hollies, Clapton Common, N.E., cashier; H. S. Hodgson, Queen Street Chambers, E.C., clerk. There are never to be more than four directors; qualification, £100; remuneration, £250 per annum, divisible. Registered by Morse, Hewitt & Farman, 37, Walbrook, E.C., solicitors.

OFFICIAL RETURNS OF ELECTRICAL COMPANIES.

Anglo-Portuguese Telephone Company, Limited (24,545).—This company's yearly return, filed April 18th last, shows that out of a nominal capital of £75,000 in £1 shares, 50,000 shares have been taken up, and that the amount resulting therefrom has been agreed to be considered as paid; and £4,020 is outstanding.

Notting Hill Electric Lighting Company, Limited (25,921).—This Company's annual return was filed on March 21st last; and shows that, out of a nominal capital of £100,000 in 6,452 ordinary, 550 founders', and 2,998 *ordinary preference* shares, all of £10 each, the whole of the ordinary and founders', and 862 of the *ordinary preference* shares have been taken up, and that the full amount has been called on each. The total sum received equals £78,640.

Anders Telephone Company, Limited (39,906).—This company's statutory return, filed on the 2nd ult., shows that out of a nominal capital of £10,000 in £1 shares, 3,607 shares have been taken up, and that £1 called on each of 607 shares, has been fully paid. A sum of £3,000 has been agreed to be considered as paid.

Ogmore Valley Electric Light and Power Supply Company, Limited (34,191).—On the 7th ult. the annual return of this company was filed at Somerset House. It shows that out of a nominal capital of £10,000, in £5 shares, 710 shares have been taken up, and that the full amount has been called on each. A sum of £3,313 has been received, and £237 is in arrear.

Oxford Electric Company, Limited (34,685).—The yearly return of this company was filed on March 28th last, and shows that out of a nominal capital of £100,000, in £5 shares, 6,586 shares have been taken up, and that the full amount has been called on each. A sum of £32,933 has been received, and £32,930 has been agreed to be considered as paid.

Phosphor Bronze Company, Limited (8,383*b*).—The yearly return of this company, made up to the 13th ult., shows that out of a nominal capital of £150,000 in £5 shares, 8,375 preference and 9,335 ordinary shares have been taken up, and that the full amount has been called on each. The total sum received is £78,550, and £11 5s. has been forfeited on 1,165 shares.

Ransomes, Sims & Jefferies, Limited (19,802).—The annual return of this company has been made up to the 26th ult., and shows that out of a nominal capital of £500,000 in £100 shares, 3,075 shares have been taken up, and that £100 has been called on each of 2,185 shares, and £50 on each of 890 shares. A sum of £263,000 has been received.

Stanhope Company, Limited (20,041).—The annual return of this company, which was formerly known as "Cordner, Allen & Co., Limited," has been filed for the past year, and shows that out of a nominal capital of £30,000, in £5 shares, 3,716 shares have been taken up, and that the full amount has been called on each. A sum of £20,000 has been received, and £10,000 has been agreed to be considered as paid.

Southampton Electric Light and Power Company, Limited (26,354).—This company's annual return, made up to the 18th ult., shows that out of a nominal capital of £30,000, in 4,000 preference and 2,000 ordinary shares, all of £5 each, 50 preference and 708 ordinary shares have been taken up, and that the full amount has been called on each. A sum of £3,735 has been received, and £55 is outstanding.

Ozone Syndicate, Limited (37,181).—The annual return of this company, filed on the 17th ult., shows that out of a nominal capital of £25,000, in £5 shares, 1,374 shares have been taken up, and that £3 2s. 6d. has been called on 447 shares. A sum of £1,256 5s. has been received, £4,635 has been agreed to be considered as paid, and £140 12s. 6d. is outstanding.

Richmond (Surrey) Electric Light and Power Company, Limited.—The registered office of this company is now situated at the Central Electric Lighting Station, Richmond, Surrey.

Telephone Company of Egypt, Limited (17,824).—This company's last return, filed at Somerset House on the 24th ult., shows that out of a nominal capital of £100,000, in 16,000 preference and 4,000 deferred shares, all of £5 each, 12,071 preference and the whole of the deferred shares have been taken up. A sum of £5 has been called on each of 71 preference shares; £355 has been received, and £80,000 has been agreed to be considered as paid.

CITY NOTES.

London Electric Supply Corporation, Limited.

THE ordinary general meeting of this company was held on Wednesday, 9th inst., at the offices, Adelphi Terrace, Strand. Mr. J. S. FORBES presided, and, in moving the adoption of the report, remarked that the further requirements of the company, arising from the growth of their business and from breakdowns and rebuildings, had involved the necessity of increasing the loan of £50,000 to £80,000. They now required a certain further amount of capital. Although the accounts were not as good as might have been expected, yet they were much better than those of the previous year (when they showed a loss of £3,914), there being a profit on last year's working of £172. The number of lamps had increased from 46,197 in 1892 to 61,924 on December 31st last. The increase in the receipts had been only 6 per cent., but the price of the unit had been materially reduced, owing to competition, the average receipt per unit in 1892 being 8d. and in 1891 10d., compared with only 6d. last year. One of the things which was affecting the London company even now was that their experiment had not yet been carried out. The real secret of success in their business was the number of lamps, the fixed charges being the same whether the number was small or large, and the cost of production not being materially greater unless the number of lamps were largely increased. Owing to the adoption of the meter they had now scarcely any lamps by contracts. Concurrently with the diminution in the price of the unit, there had been a considerable decrease in the consumption of the unit owing to the economies which their customers were now enabled almost mechanically to practise. It seemed a question whether the companies would not be driven in their own interests, and with entire justice to the consumer, to take what the law allowed them to take per unit. The revenue account was about £4,000 better than it was a year ago, although they had had to contend against many adverse incidents, which they believed would not return. They had now gone through nearly four and a half months of the current year, with a remarkable absence of those faults and interruptions which in former years had so greatly affected them. They had placed certain charges to capital account, with the entire concurrence of the auditors; and he contended that while the business was being built up, a reasonable proportion of the general charges might properly be debited to capital. He considered that this was a legitimate proceeding in itself, and that it was also a wise course to take in view of the power of the local authority to purchase these concerns at the end of their terms at their then value. Their machinery was effective for lighting 90,000 lamps, and they now had 65,000 lamps. At present they had sufficient reserve force, when the lighting was at its fullest development, to secure them against breakdowns; but what they ought to do—and to do very quickly—was to spend £12,000 in providing another dynamo, which would give them absolute security, in the character of reserve, and an increased capacity of 25,000 lamps. The loss of current in its transmission from Deptford to the distributing stations in London was only between 5 and 6 per cent. All outside debts, excluding the mortgage, were covered by £6,000.

Major C. B. WALLER seconded the motion.

In reply to questions, the CHAIRMAN stated that the mortgage was represented by the debentures, which had been issued as security for Lord Wantage's advance, and they formed a first charge on the undertaking. The directors owned two-thirds of the capital.

The motion was adopted.

The African Trans-Continental Telegraph Company, Limited.

AN ordinary meeting of this company was held yesterday at 19, St. Swithin's Lane, the Duke of Abercorn presiding.

The report, said the CHAIRMAN, explained fully the position of the undertaking, which was divided into two sections. The southern section would comprise a line from Salisbury to the Zambesi, and the northern section a line from the Zamba to the Zambesi. The construction of the southern section was further advanced than appeared from the report. They had learnt that the directors had completed their survey, and the road had been prepared for a distance of 200 miles, and the contractors stated that they would be ready to commence construction if the material were at hand. This delay, they hoped, was now overcome, and the material was now in course of transit to Salisbury. Owing to the difficulty of carriage, the material would have to be transported by native carriers. They relied on the British Government to protect their interests with the Portuguese, and they learnt that negotiations were on foot between the two Governments.

The report was then adopted.

Mr. Rochfort Maguire, and Mr. J. Wernher, were re-elected directors, and the auditors were re-elected.

Western and Brazilian Telegraph Company, Limited.

THE twenty-seventh ordinary general meeting was held yesterday at Winchester House, Mr. W. S. Andrews presiding.

In the course of his remarks the CHAIRMAN said the receipts for the half-year ended December, 1893, were £80,538 18s. 3d., as compared with £86,954 11s. 2d. for the corresponding period. Remembering the state of things that existed during the half-year under review in Brazil, that receipt was very satisfactory. The international telegraphic traffic with Brazil was suspended again and again. That position justified their action at the last meeting in not declaring a dividend, and it showed the risks being run by the company at present. The diminution was £6,600; but the remarkable point about it was that, in spite of all those circumstances, there was not a loss of traffic; on the contrary, they had actually transmitted during that period more traffic than in the corresponding period. A great deal more messages would have been carried had those interruptions not been made by the Brazilian Government. The reason why they had lost money while there was an increase in the traffic, was the unfavourable rate of exchange, which reached the lowest point ever recorded during the half-year, namely, 10⅞d. That record of lowness, he regretted to say, is being surpassed at the present time. Their dividend would have been 5 per cent. instead of 2½ per cent., had it not been for the rate of exchange. Under Abstract A there had been a reduction of £45 odd in the accounts. There was an increase, which would be permanent, of £955 in the staff expenses in Brazil. In the event of further large expansion, they would be quite capable of dealing with it satisfactorily with the present staff and appliances. The shipping account showed a small increase of £256 odd. Taking the last five years, the average cost of their ships had been £24,482 per annum, or £12,241 per six months, with which the present period's £9,382 compared very favourably. The expenses in London showed a reduction of £210 odd. The result was, that after placing £5,000 to reserve, £7,073 to debenture redemption, and allowing for the sum brought over, and £9,000 received from Platino Company in shape of dividends, there was a balance of £37,559, from which the directors recommended the shareholders to declare a dividend of 2½ per cent. for the half-year, or at the rate of 5 per cent. per annum, carrying forward £1,045 odd. The Chairman read some lengthy documents relating to the following, which is paragraph 6 in the directors' report:—"The shareholders will remember that at the general meeting of the company, held on May 12th, 1892, the directors reported that they had made an arrangement with the Brazilian Submarine Company, that in consideration of this company duplicating at once certain sections of the line, the Brazilian Submarine Company guaranteed this company a payment of £6,000 per annum. This began from June 7th, 1892. The Brazilian Submarine Company have raised the contention that under this agreement they have acquired the right to control the tariff of both companies, for the purpose of meeting competition. This company was advised by Sir Horace (now Lord Justice) Davey and by other eminent counsel who have been consulted, that the Brazilian Submarine Company has acquired no such right and has no such power, and that this company is entitled to deduct the annual sum of £6,000 from the joint purse. Under these circumstances the directors have taken credit for this sum in the accounts, and they are advised that the legal proceedings which this company has been compelled to institute in the matter, will, before the next meeting, in all probability be settled. They do not, therefore, propose to deal separately with the amount on the present occasion."

The resolution adopting the report and accounts was seconded by Mr. C. W. EARLE, and carried.

Retiring directors and auditors were re-elected, and a vote of thanks to the chairman closed the meeting.

Chagford and Devon Electric Lighting Company.—The shareholders met on Friday last week, Mr. Eaton presiding. The manager (Mr. G. H. Reed), reported that fresh applications for additional lights were constantly being received, and that the lights continued to give entire satisfaction. The company is now making satisfactory progress, and is expected shortly to be in a position to pay a satisfactory dividend. Mr. Reeves, a director, stated that he had examined the works thoroughly, and, as a practical electrician, had pleasure in reporting that the works had been carried out, and the cables laid in a manner highly creditable to Mr. Reed, and that the whole was now in a satisfactory condition.

The County of London and Brush Provincial Electric Lighting Company, Limited.—At a meeting of the board held on 10th inst., resolutions were passed appointing the Right Hon. D. R. Plunket, Q.C., M.P., and Mr. Anthony Noel Denny, directors of the company. The directors also passed a resolution electing the Right Hon. D. R. Plunket as chairman of the board.

TRAFFIC RECEIPTS.

The City and South London Railway Company. The receipts for the week ending May 13th, 1894, amounted to £905; week ending May 14th, 1893, £787; increase, £118; total receipts for half-year, 1894, £17,305; corresponding period, 1893, £16,941; increase, £364.

The Western and Brazilian Telegraph Company, Limited. The receipts for the week ending May 11th, after deducting 17 per cent. of the gross receipts payable to the London Platino-Brasilian Telegraph Company, Limited, were £2,891

SHARE LIST OF ELECTRICAL COMPANIES.

TELEGRAPH AND TELEPHONE COMPANIES.

Present issue.	NAME.	Stock or Share. ‡	Dividends for the last three years. 1891.	1892.	1893.	Closing Quotation, May 8th.	Closing Quotation, May 16th.	Business done during week ended May 16th, 1894. Highest.	Lowest.
184,500*l*	African Direct Teleg., Ltd., 4 % Deb.	100	...	...	...	101 —104	101 —104	...	...
1,134,640*l*	Anglo-American Teleg., Ltd.	Stock	£2 12s.	£2 15s.	£2 11s.	43 — 45	43 — 45	44	...
2,932,680*l*	Do. do. 6 % Pref.	Stock	£5 5s.	£5 10s.	£5 2s.	80½— 81½	80½— 81½	81¼	80⅝
2,932,680*l*	Do. do. Defd.	Stock	...	...	...	7½— 8	7½— 8	...	...
130,000	Brazilian Submarine Teleg., Ltd.	10	8 % §	6½% §	6½% §	12 — 12½	12 — 12½	12 5/16	12
18,700*l*	Do. do. 5 % Bonds	100	...	...	...	100 —103	100 —103	...	...
75,000*l*	Do. do. 5 %, repayable June 1906	100	...	...	...	108 —112	108 —112	...	...
44,000	Chili Telep., Ltd., Nos. 1 to 40,000	5	... §	10%‖ §	... §	1½— 2½	1½— 2½	...	...
10,000,000$	Commercial Cable Co.	$100	7 %	7 %	7 %	140 —145	140 —145	...	...
224,850	Consolidated Telep. Const. and Main., Ltd.	10/-	3½% §	2 % §	... §	1/16 — 3/16	1/16 — 3/16	...	...
16,000	Cuba Teleg., Ltd.	10	8 %	8 %	8 %	12 — 13	12 — 13	...	...
6,000	Do. 10 % Pref.	10	10 %	10 %	10 %	18 — 19	18 — 19	...	...
12,931	Direct Spanish Teleg., Ltd., £4 paid	5	4½ %	4 %	4 %	2⅜— 3¼	2⅜— 3¼	3	...
6,000	Do. do. 10 % Pref.	5	10 %	10 %	...	8¾— 9¼	8¾— 9¼	...	...
60,710	Direct United States Cable, Ltd., 1877	20	3½% §	3½% §	...	9½— 10	9½— 10	9⅞	9⅝
400,000	Eastern Teleg., Ltd., Nos. 1 to 400,000	10	6½% §	6½% §	...	14¾— 15½	14¾— 15	15	14⅞
70,000	Do. 6 % Pref.	10	6 % §	6 % §	...	16 — 16½	15¾— 16¼	16⅛	16
105,900*l*	Do. 5 % Debs., repay. August, 1899	100	...	...	...	107 —110	107 —110	109	...
1,294,100*l*	Do. 4 % Mort. Deb.	Stock	...	...	...	114 —117	112 —115 xd	116	113½
250,000	Eastern Extension, Australasia and China Teleg., Ltd. ...	10	7 %	7 %	7 %	15⅝— 15⅝	15⅜— 15⅝	15⅝	15 7/16
62,700*l*	Do. 5 % (Aus. Gov. Sub.), Deb., 1900, red. ann. drgs. reg. 1 to 1,049, 3,976 to 4,326	100	...	...	...	103 —106	104 —107	...	...
222,800*l*	Do. do. Bearer, 1,050—3,975 and 4,327—6,400	100	...	...	...	103 —106	104 —107	...	...
320,000*l*	Do. 4 % Deb. Stock	Stock	...	...	...	114 —117	114 —117	...	...
95,100*l*	Eastern and South African Teleg., Ltd., 5 % Mort. Deb. 1900 redeem. ann. drgs., Reg. Nos. 1 to 2,343	100	...	...	...	103 —106	103 —106	104¾	...
129,100*l*	Do. do. do. to bearer, 2,344 to 5,500	...	...	...	...	103 —106	103 —106	...	...
300,000*l*	Do. 4 % Mort. Debs. Nos. 1 to 2,016, red. 1909	100	...	...	...	104 —107	104 —107	105	...
200,000*l*	Do. 4 % Reg. Mt. Debs. (Mauritius Sub.) 1 to 8,000	25	...	...	...	105 —108%	105 —108%xd	106¼	...
180,227	Globe Telegraph and Trust, Ltd.	10	5½% §	4⅞% §	4⅝% §	8¾— 9	8¾— 9	9 1/16	8⅞
180,042	Do. do. 6 % Pref.	10	6 % §	6 % §	6 % §	15½— 15⅝	15⅛— 15⅝	15⅝	15⅛
150,000	Great Northern Teleg. Company of Copenhagen	10	8⅜% §	8⅜% §	8⅜%	21¼— 21⅜xd	21 — 21½	...	...
200,000*l*	Do. do. do. 5 % Debs.	100	...	...	...	104 —107	104 —107	...	...
17,000	Indo-European Teleg., Ltd.	25	10 %	10 %	...	45 — 47	43 — 45	...	...
37,548	London Platino-Brazilian Teleg., Ltd.	10	...	...	...	4 — 6	4 — 6 xd	...	...
100,000*l*	Do. do. 6 % Debs.	100	...	...	...	106 —109	106 —109	...	...
15,000	Monte Video Teleph. Co., Ord., 1 to 15,000	5	...	...	...	½— 1½	½— 1½	...	...
28,000	Do. do. 6 % Pref., 1 to 28,000	5	...	...	...	1 — 2	1 — 2	...	...
484,597	National Teleph., Ltd., 1 to 438,984	5	6 % §	5 % §	...	4⅜— 5	4⅞— 5⅛	5	4⅞
15,000	Do. 6 % Cum. 1st Pref.	10	...	...	...	15 — 16	15 — 16	...	...
15,000	Do. 6 % Cum. 2nd Pref.	10	...	...	...	14½— 15½	14½— 15½	...	...
119,234	Do. 5 % Non-cum. 3rd Pref., 1 to 90,950	5	...	...	...	5⅜— 5⅝	5⅛— 5⅜	5 1/16	5⅛
925,017*l*	Do. 4½ % Deb. Stock Prov. Certs. ...	...	...	...	...	114 —116	114 —116	115	114¼
48,800	New Teleph., Ltd., 25,901 to 74,700; £4 paid	10	...	...	...	... ...	... ...	...	...
171,504	Oriental Teleph. & Elec., Ltd., Nos. 1 to 171,504, fully paid	1	...	...	...	⅜— ½	⅜— ½	...	...
100,000*l*	Pacific and European Tel., Ltd., 4 % Guar. Debs, 1 to 1,000	100	...	...	...	102 —105	102 —105	...	...
11,839	Reuter's Ltd.	8	5 %	5 %	...	5½— 6½	5½— 6½	...	...
3,381	Submarine Cables Trust	Cert	...	...	...	111 —116	112 —116	...	...
58,000	United River Plate Teleph., Ltd.	5	...	...	...	1½— 2	1½— 2	...	...
146,370*l*	Do. do. 5 % Debs.	Stock	...	...	...	90 —100	90 —100	...	...
15,609	West African Teleg., Ltd., 7,501 to 23,109	10	4 %	..	...	3 — 5	3 — 5	...	...
249,900*l*	Do. do. do. 5 % Debs.	100	...	...	...	100 —103	100 —103	...	...
30,000	West Coast of America Teleg., Ltd.	10	...	...	...	2½— 3	2½— 3	...	...
150,003*l*	Do. do. do. 8 % Debs., repay. 1902	100	...	...	...	105 —109	105 —109	106	...
64,242	Western and Brazilian Teleg., Ltd.	15	4 %	2½%	...	7½— 8	7½— 8	7⅞	7⅝
33,129	Do. do. do. 5 % Cum. Pref. ...	7½	...	...	...	6½— 7	6½— 7	6⅝	6¼
33,129	Do. do. do. 5 % Def.	7½	3 %	...	...	2 — 2½	2 — 2½	2⅛	...
178,200*l*	Do. do. do. 6 % Debs. "A," 1910 ...	100	...	...	...	106 —109	106 —109	...	...
222,700*l*	Do. 6 % Mort. Debs., series "B," red. Feb. 1910	100	...	...	...	106 —109	106 —109	...	...
88,321	West India and Panama Teleg., Ltd.	10	¼%	¼%	...	1¼— 1⅜	1 — 1¼xd	1¼	...
34,563	Do. do. do. 6 % 1st Pref. ...	10	...	...	...	10½— 11	10¼— 10⅜xd	...	...
4,669	Do. do. do. 6 % 2nd Pref. ...	10	...	...	...	9 — 10	9 — 10 xd	...	...
80,000*l*	Do. do. 5 % Debs. (1917) No. 1 to 1,000	100	...	...	...	109 —112	109 —112	...	...
$1,214,000	Western Union of U. S. Teleg., 7 % 1st Mort. Bonds ...	$1000	...	...	...	110 —115 xd	110 —115	...	...
169,000*l*	Do. do. 6 % Ster. Bonds.	100	...	...	...	100 —104	100 —104	...	...

ELECTRICITY SUPPLY COMPANIES.

20,510	Charing Cross and Strand Electy. Supply, 1 to 6, 215 to 718, and 10,001 to 30,000	5	...	5 %	4½%	4½— 5½	4½— 5½	...	...
40,000	City of London Elec. Lightg. Co., Ltd., Ord. 40,000—180,000	10	...	...	...	12 — 13	12 — 13	...	...
20,000	Do. do. 6 % Cum. Pref., 1 to 20,000	10	...	6 %	6 %	13½— 14	13½— 14	13 1/16	13¾
100,000	Do. 5 % Deb. Stock, Scrip. (iss. at £115) £75 paid	...	...	...	...	83 — 85	83 — 85	...	...
19,900	*Electy. Supply Co. of Spain, 101 to 20,000...	5	...	...	...	... ...	... ...	...	...
5,523	†Liverpool Electric Supply, £4 10s. paid	5	...	...	...	5⅞— 6⅛	5⅞— 6⅛	...	...
39,477	Do. do.	5	4½%	5 %	5 %	6½— 6⅝	6⅝— 6½	6½	6 7/16
49,900	*Metropolitan Electric Supply, Ltd., 6,101 to 50,000 ...	10	1 %	2 %	...	7½— 8 xd	7½— 8	7⅞	7 15/16
100,000*l*	Do. 5% Deb., 1 to 10,000 in bonds of £10, £20, £40	...	...	...	...	108 —111	108 —111	110¼	...
6,452	Notting Hill Electric Lightg. Co., Ltd.	10	...	...	...	4½— 5⅛	4½— 5½	...	...
19,980	St. James's & Pall Mall Elec. Light Co., Ltd., Ord., 101-18,780	5	8½%	7¼%	4¼%	6¾— 7¼	6¾— 7¼	...	...
20,000	Do. do. 7 % Pref., 20,081 to 40,080	5	7 %	7 %	7 %	8 — 8½	8 — 8½	8⅝	...
59,900	*Westminster Electric Supply Corp., Ord., 101 to 60,000 ...	5	...	3½%	4 %	5¾— 6¼	5¾— 6¼	6 3/16	...

* Subject to Founder's Shares. † Quotations on Liverpool Stock Exchange.

‡ Unless otherwise stated all shares are fully paid. ¶ Dividends paid in deferred share warrants, profits being used as capital.

Dividends marked § are for a year consisting of the latter part of one year and the first part of the next.

SHARE LIST OF ELECTRICAL COMPANIES—*Continued.*

ELECTRICAL RAILWAY, MANUFACTURING, AND INDUSTRIAL, COMPANIES.

Present Issue.	NAME.	Stock or Share. ‡	Dividends for the last three years. 1891.	1892.	1893.	Closing Quotation, May 8th.	Closing Quotation, May 16th.	Business done during week ended May 16th, 1894. Highest.	Lowest.
90,000	Brush Elecl. Enging. Co., Ord., 1 to 90,000...	3	...	6 % §	6 % §	2⅞— 3	2⅞— 3	...	...
90,000	Do. do. Non-cum. 6 % Pref., 1 to 90,000	2	...	6 % §	6 % §	2⅛— 2⅜	2⅛— 2⅜	...	...
125,000/	Do. do. 4½ % Deb.	Stock	...	...	...	107 —110	108 —111	109⅝	...
630,000/	City and South London Railway	Stock	...	⅝%	⅝%	28 — 30	29 — 31	30	...
20,000	Crompton & Co., Ltd., 7 % Cum. Pref. Shares, 1 to 20,000	5	7 % §	7 % §	7 % §	3¼— 3¾	3 — 3½	...	...
50,000/	Do. do. 5 % 1st Mort. Debs., 1—400 of £100, and "A" 1—200 of £50 each	...	...	...	...	95 —100	95 —100	...	...
120,000	Electric Construction, Ltd., 1 to 120,000	2	...	...	...	¼— ⅜	¼— ⅜	...	...
12,845	Do. do. 7 % Cum. Pref., 1 to 12,845 ...	2	...	...	...	1¼— 1⅜	1¼— 1¾	...	...
100,000	Elmore's French Patent Cop. Deposg., Ltd, 1 to 66,750 ...	2	*nil*	*nil*	*nil*	1/16— 3/16	1/16— 1/16	...	...
91,195	Elmore's Patent Cop. Deposg., Ltd., 1 to 70,000	2	*nil* ¶	*nil*	*nil*	⅛— ⅜	1⅛— 1⅜	1⅜	⅜
67,385	Elmore's Wire Mfg., Ltd., 1 to 67,385, issued at 1 pm.	2	*nil*	*nil*	*nil*	¾— 1	1⅛— 1⅜	1¼	1⅛
20,000	Fowler-Waring Cables, Nos. 301 to 20,300	5	*nil* §	*nil* §	*nil* §	½— 1⅛	½— 1⅛	...	...
9,600/	Greenwood & Batley, Ltd., 7 % Cum. Pref., 1 to 9,600 ...	10	7 %	...	...	6½— 7½	6½— 7½	...	...
6,837	Henley's (W. T.) Telegraph Works, Ltd., Ord.	10	5 %	5 %	5 %	6 — 7	6½— 7½	...	...
50,000	India-Rubber, Gutta Percha and Teleg. Works, Ltd. ...	10	12½%	12½%	12½%	23 — 24	23 — 24	23⅝	23¼
200,000	Do. do. do. 4½ % Deb., 1896	100	...	...	...	102 —104	102 —104	...	...
37,500	†Liverpool Overhead Railway, Ord.	10	...	...	1 %	7 — 7¼	8⅜— 8⅝	...	...
6,295 †	Do. do. Pref., £8 paid	10	...	...	...	12¾— 13¼	12¼— 12⅝	12½	...
78,949	Swan United Electric Light, Ltd., £3½ paid	5	11 % §	10 % §	7½%§	2 — 2½	2 — 2½	...	...
37,250	Telegraph Constn. and Maintce., Ltd.	12	20 %	15 %	20 %	39 — 41	39 — 41	40½	39¼
150,000/	Do. do. do. 5 % Bonds, red. 1894	100	...	...	...	... ...	104—107	...	...

† Quotations on Liverpool Stock Exchange. ‡ Unless otherwise stated all shares are fully paid. ¶ Last dividend paid was 50% for 1890.

Dividends marked § are for a year consisting of the latter part of one year and the first part of the next.

CROMPTON & Co.—The dividends paid on the ordinary shares (which have not a Stock Exchange quotation), are as follows: 1892—0% §; 1891—7% §; 1890—8% §.

LATEST PROCURABLE QUOTATIONS OF SECURITIES NOT OFFICIALLY QUOTED.

Birmingham Electric Supply Company, Ordinary of £5 (fully paid), 5¼—5¾.

Electric Construction Corporation, 6 % Debentures, 87—92.

Electric and General Investment, shares of £5 (£1 paid), 1⅞—2¼.

Electricity Supply Corporation, Ordinary of £5, 5—5¼.

House-to-House Company (£5 paid), 1—1½.

Do. do. 7 % Preference, of £5, 5¼—5½.

Do. do. 6 % Debentures of £100, 101—103.

Kensington and Knightsbridge Electric Lighting Company, Limited, Ordinary Shares £5 (fully paid) 4¾—5¼; 1st Preference Cumulative 6 %, £5 (fully paid), 6¼—6⅜.

Liverpool Electric Supply, £5 (fully paid), 6½—6⅝.

Do. do. £3 10s. paid, 4½—4⅝.

London Electric Supply Corporation, £5 Ordinary, ⅞—1⅛.

Queen Anne's Mansions Lighting and Heating Company, 6 % £100 Debentures, 101—103.

Yorkshire House-to-House Electricity Company, £5 Ordinary Shares (£4 10s. paid), 4¼—4⅜.

Bank rate of discount, 2 per cent. (February 22nd, 1894).

PROCEEDINGS OF SOCIETIES.

Institution of Electrical Engineers.

AT the ordinary general meeting, held at the Institution of Civil Engineers on Thursday evening, May 10th, Sir David Salomons presiding, the discussion on the paper by Mr. Crompton, on "The Cost of Electrical Energy," was resumed.

Mr. CROMPTON first drew attention to a diagram which gave a 24-hour test of the Chelmsford power station. It was interesting from many points of view, but most interesting of all was the fact that the table, which related to the works, J, of his paper, showed that on this occasion, when a careful test was made, the lbs. of water evaporated per lb. of coal rose to a little over 9; that was to say, the same boiler and the same apparatus which on the year's run came out at 5·2 evaporated only, under the careful conditions of the test got as high as 9. That was the class of test he recommended to be taken at frequent intervals in stations, in order to enable the engineer in charge to know what their plant was capable of doing on the 24 hours' cycle. There was no doubt that, if they took the same pains throughout the year as on that particular occasion, they would get for every day in the corresponding period of the year as good a result as on that occasion; and he might say that a good deal of the improvement shown in the boiler efficiency was due to the enormous amount of information which had been kindly afforded him, and which he had got himself for the purposes of the paper; so that if the paper had done no one else any good, he certainly had profited by it, and he hoped it might be equally useful to others.

Major-General WEBBER said the great interest which the paper had excited would, no doubt, as Mr. Raworth had said, leave a deep impression on all those who had heard it; but he was one who, after reading it carefully, felt that much that was contained in it was open to criticism, and perhaps even to sharp criticism. Before proceeding to the remarks he would like to make, especially on Table VI., he would ask Mr. Crompton whether he selected as his ideal output a consumption of 500,000 units per annum. He told them that his paper was framed after deep and careful consideration of the results of the various known systems, and therefore he (Major-General Webber) must assume that he was dealing with a load for lighting purposes. Now, in Kensington, the part of London with which Mr. Crompton was best acquainted, the speaker would like to remind him that the greater part of the load there was certainly for supplying glow lamps, and if they took the known revenue earned per annum by lamps in that district, that was 8s. 6d. per 8-candle lamp, and even if they went so far as to assume that it was 12s. per annum per 8-candle lamp, as it was in some other parts of London, they found that under the conditions of that ideal load the capital expenditure per lamp was from £1 6s. to £1 16s. He was therefore at a loss to know upon what system, especially in the Metropolis, Mr. Crompton framed his estimate, or his possible estimate. For instance, in Kensington, which was supplied by three companies, by the published returns for the last day of last year they had a capital expenditure of £3 per lamp, and he would ask Mr. Crompton, did he believe, especially as regarded two of the companies with which he was well acquainted, and which they must hope were on the way to that ideal, that he was going to reduce that £3 to £1 6s.? Did he forget that of the 60 miles of streets, which would be the ultimate area which would have to be lighted in Kensington, only about four miles had mains along both sides? Did he forget that the total plant of these three companies had a capacity of 2,300 E.H.P. output, and did he believe that when that reached 13,500 output E.H.P.—the capacity that Kensington should have in a few years—he would then have come down to a capital expenditure of £1 6s. per lamp? He (the speaker) did not think he did, and therefore wished to ask him where his ideal station was to be found if not in a district like Kensington, with which they all admitted he was well acquainted. He would now come to the question of the mode in which the author collected his information. He had seen the letter which he wrote to various engineers, and that letter, after asking questions which he (the speaker) should say were more or less framed with a view to obtaining answers in a certain direction, informed the engineers to whom it was written that if they did not give him a reply, or if they gave only a partial reply, he was prepared to fill up with data which he had in his possession. From one company to which he wrote he got no information, and the speaker thought the reason was obvious. He sympathised with the engineer who did not give the information sought. Laying aside the question of the views of directors in the matter, he believed engineers would be very willing to give the fullest information if they were to have something to do with the compilation of the tabular statement. Chelsea was one of the most mixed stations in this country. The paper which he (Gen. Webber) read two years ago described that station, and stated that while accumulators were the main source of supply, there was also a distribution between transformer motors and accumulators, showing a maximum loss of 30 per cent.; with the transformer motors alone a loss of very little more than 15 per cent., and with the direct current portion of the supply a loss between the terminals of the dynamo and the consumers' terminals of 10. Therefore he did not think it was quite right to include the Chelsea system as not being one of those mixed systems purposely left out of the report for purposes of comparison. Mr.

Crompton told them at the last meeting that the figures 62 were figures which might be left out of the table. But it was not necessary to tell anybody, when he put the figures 62 in the proof, that there was a loss of 38 per cent., for anyone comparing 142 and 88 could see that 62 was the result. All the other figures in that column were compiled in the same way, and therefore it only required somebody to put two and two together to bring out 62. He thought the term "efficiency of distribution" was altogether a misnomer, because efficiency of distribution did not at all mean what he believed Mr. Crompton intended to convey. It might be efficiency of copper, as he hinted was the opinion of American engineers; and therefore the standard of comparison was one which appeared to him (General Webber) to be altogether faulty. If Mr. Crompton had confined himself to a comparison of companies' systems with which they knew he was acquainted, and had given them that information which he undoubtedly possessed, and not come forward as the compiler and recorder of information as regards the completeness of which he told them that some was filled in anonymously—if he had left out all the information regarding companies with which he was not acquainted, they would not have complained. He sympathised greatly with the engineers of the stations dealt with. No doubt there would be a flood of letters from them, and though they might answer to the helm to a certain extent, he did not believe they would agree with the accuracy of Table VI., which he regarded as the crux of the whole paper, as far as the two points to which he had referred were concerned. The first two pages of Mr. Crompton's paper contained all the information which was usually put into the prospectus of a joint stock company. When he told them that he expected in a very short time to supply electricity at 3d. per unit, out of which he was going to make a profit of 1·68d., and then told them that the London companies were a long way from having a load factor of more than 20, he left on the minds of his hearers great doubts as to whether he himself was convinced of the accuracy of his facts.

Mr. Mark Robinson said this was a practical paper, and one of great importance. Mr. Crompton had shown them in times past that if he was occasionally ahead of his times in what he said, some, at any rate, of his predictions came true, and he hoped this might be the case with the 25 lbs. of coal per unit. At the same time he would like to say a few words upon the basis of that calculation. He by no means wished to suggest that the calculation was widely wrong, if it were wrong at all, but he thought it would be instructive to review the figures a little. It rested on three factors, amongst others, first the evaporation by the boiler of 12 lbs. of water per lb. of coal; secondly, the consumption by the engine of only 12 lbs. of steam per I.H.P., and thirdly, only a small amount of friction. With regard to the boilers, all he would say was that the figures, 12 lbs. per pound of evaporation, or 10 lbs. in ordinary work, including all losses, was beyond the present practice, but they were all improving, and he hoped they might improve up to that. With regard to the dryness of steam from water-tube boilers, his own company had lately taken up a water-tube boiler from which they hoped great things, and from which they knew they got dry steam. Thames Ditton had, he was afraid, been responsible for a great deal of the unbelief in times past about the possibility of getting dry steam from water-tube boilers. They had had one under test there with really extraordinary results, there being about ¼ per cent. of moisture only. Mr. Crompton said his experience of Babcock boilers was that they were able to force them very much beyond their original capacity, and they had still given dry steam. They had had just the same experience with another boiler. They had driven it to double its ordinary capacity, the tests being carried out more with the view of showing that the boiler was wrong than that it was right, and the boiler had beaten them fairly. They had tested a Babcock boiler about the same time, and with the same result. Thames Ditton had spoken on the subject before, and he thought they owed some recantation on this matter. They had proved now that their own boiler gave splendidly dry steam, and it was only just to say that a water-tube boiler would give dry steam; they did not claim it for their own in particular. So much, in the opinion of many, depended on water-tube boilers in the future, that no doubt they would be glad to hear testimony as to their efficiency. The figures mentioned for the consumption of steam, 12 lbs., had been reached, he believed, by the Sulzer engine. One could wish that the results were corroborated by concordant results of a good series of progressive trials, or at least that they were supported by many repeated trials, but it would be unreasonable to expect that a large engine, which could only be put under its proper load when under proper working conditions, should be tested as they tested at Thames Ditton. The undoubted competence of the observers in the case of the Sulzer trials commanded respect and acceptance; 12 lbs., and less, was recorded on first-rate authority. Mr. Willans's best experimental figures at Thames Ditton were about 12 8 lbs., and the best guarantee they had ever given was 13 lbs. for a large marine engine. In comparing with a Sulzer engine, it might be said that a high-speed engine might be made to work upon 13 lbs. of water. He had no doubt they could, by carrying expansion much further, and by jacketing to the utmost, and carrying out every refinement possible, bring that high speed engine down to the same figure as the Sulzer engine; but, in doing so, they would have to make a bigger engine, with larger cylinders and pistons and more ring friction, and, of course, at much more cost. With a larger ring friction they would get smaller brake efficiency in the engine, and smaller combined efficiency in the plant. He was afraid the combined efficiency of 86 to 88 per cent., upon which Mr. Crompton relied, would not be forthcoming. That was a point he wanted to bring out; they could not eat their cake, and have it. For small boiler consumption they wanted large cylinders, and he should say large friction, and that was incompatible with high combined efficiency. For high combined efficiency they must have a high rate of expansion and large cylinders. They must not, in fact, take the largest steam consumption and the smallest friction, and expect to get both in the same engine. Mr. Crompton's paper dealt with the future, and they were all improving; it might be that they would eventually reach his figures, but they were not there yet. These were only small matters in the criticism of Mr. Crompton's figures, but it must be borne in mind that they must get the maximum steam economy and the minimum friction. Mr. Raworth, at the last meeting, threw new light on the subject in bantering Mr. Crompton on his success in what Americans would call twisting the other animals' tails. Mr. Raworth passed that on, and tormented the Willans engine a little. The Willans engine was very much referred to, and that must be his excuse for taking it as the datum. Mr. Raworth said that the Willans engine certainly had a very good brake efficiency. He (the speaker) believed that was notorious, so that there was no harm in referring to it. Mr. Raworth said its brake efficiency was 89½ to 90 per cent., which showed very good observation on his part, for those were very nearly the right figures. But so, he went on to say, had every other engine—that was, every vertical engine—in fact, some vertical engines had a 92 per cent. efficiency. This was very good hearing, but he would like very much to know how that was arrived at. Compound or triple expansion engines were not very easy to handle on brake trials, and very few people were lucky enough to have the brakes with which to test them. In many cases reference was made to friction curves, diagrams made with engines running light; but it did not seem to him safe to say that because you had taken a friction curve with an engine running light and it showed only 8 per cent. friction consumption that the brake efficiency was 92 per cent. Mr. Willans showed that in the case of his engine it was so, and very interesting were those parallel lines which showed that the useful load was constant—at least as regarded the combined engine and dynamo, and everybody agreed, he believed, that there was very little difference in the losses in a really good dynamo—and that the engine loss in the Willans engine was pretty constant all through; but he thought the Willans engine differed in that respect from ordinary engines. Mr. Raworth stated that if the Willans engine were double-acting it would have considerably less friction, but that meant ring friction, and ring friction was constant. There were four principal kinds of friction, it appeared to him, which an ordinary engine suffered from. In the first place there was the friction of rings, piston rings and valve piston rings. That certainly was practically independent of the load. Then, secondly, there was slide valve friction, which in most engines rose rapidly with the load, but from that a single-action engine was exempt. Then there was the bearing friction, which, when bathed in oil, seemed by the trials they had made not to rise with the load, but which, they believed, in the case of double-acting engines, or at any rate where the bathing in oil was not so complete, did increase with the load. Fourthly, there was some increase of friction where the pressure on the brasses was not all in the same direction, due to what the Americans called lost motion. They did not know what that was. Thus it would appear that the single-acting engine had only sources of friction which were approximately constant, whereas that with which Mr. Raworth compared it had causes of friction which increased with the load; therefore they were not able to accept friction curves as conclusive upon brake efficiency. Whilst suggesting that others were theorising, he was himself theorising; but it might be of interest to Mr. Raworth and others if he mentioned that they hoped to bring this question to a practical test before long. Messrs. Mather & Platt were putting in hand for them one of those water-brakes like Prof. Osborn Reynolds used, which got rid of many questions which were supposed to interfere with the accuracy of certain forms of brake strap, and was large enough to absorb 1,200 H.P. They hoped to run their largest engines on that brake, and really find out something about them. The mean of a number of engine tests made on engines which were new and stiff, and which would certainly give better results afterwards, came out at 90·6 brake efficiency. Those tests were made with the brake arranged on what was usually known as Halpin's plan, and they believed the figures were reliable. That would no doubt come to the 91 per cent. which Mr. Crompton had given as the best standard practice, and which he believed was very good practice indeed. Mr. Crompton made an excellent practical suggestion in one small matter, the use of a pressure gauge on the steam chest. If people knew how useful such an arrangement was, they would always use it. They always used them in their electric launches, and were able by their means to see at any time how fast the boats were going. Such a gauge would not, of course, be applicable if an engine had automatic expansion gear; that was one reason why, with their automatic expansion gear, they were providing an index which showed what the cut-off was at a certain time.

Mr. W. Geipel joined with others in eulogising the paper under discussion, which, he said, contained information of the greatest interest and importance to those engaged in electricity supply, more especially as it came from one whose experience in central station working was unique. That the cost of supply should be within measurable distance of 3d. per unit, including profit, was at least encouraging to those who had not given the subject of cost more careful attention. While at this figure, the dictum pronounced by Mr. Preece that the electric light is the poor man's light, could not longer be denied by the most conservative. But he hoped to show that Mr. Crompton had been altogether too modest. Look at his ideal costs, and they would there see that out of a total of 3d. he had put 1·68d. to profit. A large portion of the paper was occupied in discussing the item coal, which in the ideal cost was put at ·27d, or 1s. 6d. of profit. He had ventured to place on the wall a diagram showing the effect on the total cost of a proportional increase or decrease in the cost of those two items, from which they would observe that a range of 40 per cent. above to 80 per cent. below Mr. Crompton's ideal made a difference in the price per unit of ·35d. in the case of coal, against 2d. in that of profit. Again, he could

not imagine why Mr. Crompton was so eager in reducing salaries, wages, stores, and sundries to a mere fraction of what they at present cost, and yet that he was content to leave the most serious item, profit, in other words, the first cost of the installation, to others. He said, in speaking of this item, "We engineers have nothing to say in controlling these figures." He (the speaker) did not for one moment agree with him in this. The reduction of the cost of electricity supply stations was very largely indeed the business of engineers. In his opinion the present high price of electric supply was due mostly to an insufficient consideration having been given to this question of first cost. It was certainly not always judicious to incur every possible expense in providing for saving in coal and labour and stores, without regard to the consideration of outlay. For example, costly chimneys were frequently erected when a less outlay in this respect would suffice, or condensers and economisers were erected capable of dealing with the maximum load, the consequence being that a large portion was utilised but a mere fraction of the year. Was it not the function of an engineer to so lay out the capital that the cost of interest, depreciation, and the working expenses were together a minimum? Mr. Crompton did not say precisely how he arrived at his first cost of 2s. per unit sold per annum; but if his basis were the 20 per cent. load factor to which he alludes further on, his figures mean a cost of £175 per kilowatt. It was his opinion that the first cost might frequently be less than one half this figure, not certainly on the low tension direct current system upon which he feared Mr. Crompton had based his figures, but with the more modern alternate current system, using high tension feeders, supplying by transformers a low tension network. He did not see why the improvements which were being made in the efficiency, and the reduction of the cost of alternators and transformers, should not enable them in future to arrive at a figure of £60 per kilowatt under favourable circumstances; at any rate this was, he held, very much nearer possibility than some of Mr. Crompton's ideal costs. General Webber gave them the figure, £75, in a recent paper read before the Institution, as the cost of the City of London scheme, where there was unusual expense in the street work. Taking even £80 per kilowatt, and applying Mr. Crompton's 20 per cent. factor, and his own figures for works load cost and management, they got:—Total works cost, ·5d; maintenance, 2 per cent. on 11d., ·22d.; management, ·42d.; profit, 7 per cent. on 11d., ·77d.; total, 1·91d. That is less than 2d. per unit. He was glad to hear that Mr. Crompton had recently become a convert to the alternate current system, because he felt that with further experience in the first cost of this system, and provided that he still stood by his ideal figures as to works cost, he would at a future day corroborate his figures of 2d. per unit. He was not so sanguine, however, as Mr. Crompton upon one or two points. A 20 per cent. load factor was not often recorded in central stations in this country; even 15 per cent. was considered good. Then, with regard to salaries and wages, Mr. Crompton had taken these at ·2d., or one-quarter of the average of the eight lowest records of the companies in *Lightning's* list, while water and petty stores he had at ·03, or one-third of the eight companies' average. He did not see how coal could possibly be reduced to 2½ lbs. per unit, but believed 4 lbs. might be reached, even with English coal, which could be obtained at 7s., and less, per ton in many towns, making the cost of coal ·15d. per unit. Take, then, double Mr. Crompton's figures for petty stores, wages, and superintendence, and £60 per kilowatt with a 15 per cent. load factor, they obtained:—Fuel, ·15; water, ·01; stores, ·04; wages, ·02; superintendence, ·2; total, ·60; maintenance, 2 per cent. on 10·9d., ·22; management, ·42; profit, 7 per cent. on 10·9d., ·76; total, 2·00d., as what might be expected in towns favourably circumstanced as to load factor and fuel or other source of power, *provided always they had had the foresight to adopt the alternate current system.* He was afraid that the figure Mr. Crompton had given, namely, 12 lbs. of water evaporated at 150 lbs. pressure per lb. of coal, was one the attainment of which would gladden the hearts of legions outside the electrical profession. He was aware that under specially favourable circumstances, with the best fuel and conditions, and deducting ashes, this result might be attained on occasion, but he had not yet found anything approaching this in practice, even under circumstances much more favourable than those which obtained in central station working. In fact, further on in the paper a lower figure, namely, 10 lbs., was spoken of. At the same time, there could not be a doubt that there was room for improvement; and, perhaps, he might be permitted to mention two methods of setting boilers which he had designed with a view to reducing the losses due to the radiation from the boilers, which were put out of use each night, diagrams of which were on the wall. One was applied to the Babcock-Wilcox boiler, which, as they were aware, was enclosed by a large amount of brickwork, absorbing, as Mr. Crompton pointed out, a proportional amount of heat. In order to reduce this, he had introduced a thermal insulator in the form of an air space in the middle of the side walls, so that the outer half did not absorb so much heat as heretofore. This setting had been applied to the boilers at the Huddersfield and other electricity works, and had, he understood, been since adopted by Messrs. Babcock at other places with good results. The other method related to cylindrical boilers of the Lancashire and similar types which he arranged as follows:—The gases, after passing through the boiler and under, were diverted into a main flue, which led on to the economiser; from this they passed by a large side flue round each boiler consecutively to the chimney, so that whatever number of boilers happened to be out of use at any time they were kept warm by the waste gases from those in use. There were other advantages in this type of setting, to which, however, he would not refer. He did not agree with Mr. Crompton that the Lancashire boiler was unsuitable in all cases for electric lighting purposes, nor that its efficiency compared so unfavourably with other boilers. The comparison given between the marine boiler at Glasgow and the Lancashire by Bryan-Donkin was certainly unfavourable to the Lancashire, but of all boilers the Lancashire was most unsuited for burning coke. It would probably be found that with bituminous coal the results would be reversed. Mr. Crompton spoke of a difficulty in utilising the hydrogen constituents of the coal. Might he suggest that provided there was an excess of the proportion of hydrogen above that required for combining with the oxygen already in the coal there should be no difficulty with a suitable furnace in utilising the heat of combustion? He thought it had been demonstrated that bituminous coal could be burnt under proper conditions without causing smoke, while the results of tests of the flue gases, so far as he knew, did not show unoxidised hydrogen to any extent. There was this advantage with the bituminous or flaming coal, namely, that the heat was less confined to the grate. In other words, it enabled a more gradual use to be made of the boiler-heating surface. At the same time he quite agreed with the author that anthracite coal had many advantages. He merely pointed out that there were numerous districts in this country where bituminous coal could be used with far greater economy than anthracite or Welsh coal. He endorsed most cordially what Mr. Crompton said of the Babcock boiler, and there were one or two important considerations in its favour which he had overlooked. The great point which accounted for the suitability of this class of boiler was in the small quantity of fuel required for raising steam, which was largely due to the small proportion of water contained in the boiler. While in the Lancashire boiler there was as much as ·8 cubic foot of water per square foot of heat surface, there was but ·14 in the Babcock. Allowing for the greater evaporative power of the Lancashire heat surface, there were for approximately every kilowatt of maximum output 4 cubic feet of water in the Lancashire against 1 cubic foot in the Babcock, to be raised to evaporating point daily. Each cubic foot of water required about 1 lb. of coal to raise it from 212° F. to 366° F. So that with a 3,000 kilowatt plant, such as he took it Mr. Crompton spoke of, there would be about 12,000 lbs. required for the Lancashire against 3,000 lbs. for the Babcock for daily steam raising. For steaming there would probably be required about 33,000 lbs. per diem with either boiler. The proportion then was for the Lancashire $\frac{12,000}{33,000} = 36$ per cent., and for the Babcock $\frac{3,000}{33,000} = 9$ per cent. only for raising water to evaporating point; the net result being, for the Lancashire, 3 lbs. against the Babcock 2·4 lbs. per kilowatt hour. He had used Mr. Crompton's figures for coal and load factor in calculating the above. He was inclined to believe that there were cases where it would be advantageous to use a combination of Lancashire and Babcock boilers where bituminous coal was cheap, using the Lancashire continuously and the Babcock for the top parts of the coal curve. He did not think that in placing the Babcock and Economic boilers side by side on the score of safety, justice had been done to the Babcock boiler. In the case of the Economic boiler, if he understood correctly, they had the internal flue, which was after all the most dangerous part of a boiler, while in the Babcock there was not only the absence of internal flue, but the part of the boiler near the fire, and most susceptible to overheating, were tubes containing water which could not cause an explosion. He was sorry to see that Mr. Crompton recommended the use of boiler fluids, &c., to keep the scale and sediment from affecting the surfaces; he was of opinion that the boiler was not the proper place to effect the deposit of mud and scale. The better cure was the removal of the impurities from the water before it entered the boiler. This could generally be done in the feed water heater or economiser; both carbonate and sulphate of lime, which were the chief impurities, were precipitated at about 260° F., or the feed might be treated before it passed into the feed pipes with purifying apparatus. Before leaving the subject of boilers, it might interest the Institution to know that in the year 1888 he made a test at the Lyceum Theatre, Edinburgh, with a view to ascertaining how much water could be evaporated at 150 lbs. pressure by forcing a 25 actual H.P. Babcock boiler, when he obtained about 6 lbs. of water per square foot of heat surface, and this boiler was running daily two 25-H.P. compound engines, and that without any excessive repair. Of course, when running on full load the efficiency was low, and he did not mean to advocate habitual overpressing to this extent; in this case there happened to be no option. This reserve power was, however, of enormous importance, for it enabled the passing over of the peak of the load curve with a smaller quantity of boilers, and though at the moment of forcing there might be some loss of efficiency, it was probably more than counterbalanced by the saving in steaming further boilers, to say nothing of the saving in capital outlay in having less boilers to provide. He was glad to see this forcing advocated by Mr. Crompton, and was of opinion that it might often be worth while providing blowing apparatus to be used during the heavy load period, which, after all, presented a mere fraction of the whole year. Mr. Crompton referred to the average efficiency of the existing alternating systems as 66 per cent., but this was largely due to the use of separate transformers on scattered installations, where the same amount of money expended in distributing plant on the low pressure system would have produced a most serious loss of potential and energy, certainly far exceeding the 44 per cent. spoken of. It was interesting to know, as an example of the flexibility of the alternating system, that at Huddersfield they had already run feeders out to the distant suburbs, where residential houses were being supplied; while in Bradford, where plant had been in operation so long, the suburban folk were still crying out for a supply. Even were the efficiency of alternating stations so low as Mr. Crompton put it, though he did not admit it, they had merely to refer to the curves on the wall to see the effect of this question of fuel as compared with capital outlay. The result of banking the transformers was, however, making enormous improvements in this respect, and in Mr. Crompton's table this was instanced by the 82 per cent. of the City of London Company. He did not see wherein lay the difference in economy obtained by

parallel running with continuous current dynamos as compared with alternators. He was glad that Mr. Crompton advocated superheating the steam. He had for several years been an advocate of this practice, but instead of resorting to the use of super-heaters, of which Mr. Crompton rightly points out the difficulty, why not evaporate the steam at a higher pressure, using reducing valves on each boiler? There was no difficulty in working a Babcock boiler at 200 lbs., and if steam at this pressure were reduced to 150 lbs. pressure in the steam pipes, they would at once have approximately the 8 per cent. super-heating mentioned by Mr. Crompton. The loss in the steam pipe was undoubtedly of the most serious nature, and every precaution should be taken to subdivide the steam pipes into sections controlled by valves, so that only that portion of the steam pipe which was absolutely necessary at the time being was used. The following rough calculations he had made might be of interest. Each square foot of lagged pipe when the steam was 300° F. above the atmosphere radiated 300 British thermal units per hour, which amounted to about 300 lbs. of coal per annum if in continual use. Uncovered surfaces, such as valves and flanges, radiate 1,000 B.T.Us. per hour, and required about 1,000 lbs. of coal, say half a ton per annum. He did not know exactly what area of pipe there would be in Mr. Crompton's ideal plant, but put it at 3,000 square feet of lagged and 1,000 of unlagged pipes, this would require about 850 tons of coal per annum; of course, by turning off the sections of the pipes not in use, this figure was materially reduced. Mr. Crompton spoke of the use of surface condensers as entailing the working out of several very difficult problems connected with the thorough filtering of the oil contained in the exhaust steam. Why use oil in the cylinders at all? It was a common practice in the Mercantile Marine, and Mr. Raworth never had a drop put into his cylinders, condensing or non-condensing. This was a very simple solution of the difficult problem. He confirmed all Mr. Crompton said as to the wastefulness of direct-driven feed pumps. His attention was first called to this about six years ago, when he made two six-hours' tests on a 20 H.P. Babcock boiler. In the first case a Worthington pump was used, pumping from a tank overhead, in which the water was heated to 212° F., when seven pounds of Scotch coal were required per H.P. hour. When using an injector feeding from a cold water tank there were only 6 lbs. of the same coal consumed per H.P. hour. This was no doubt due first to the very slow piston speed at which those pumps worked, and secondly, to the steam ports being full open to the end of the stroke. Since those tests his company had designed a pump driven by spur gearing from a high-speed engine, from which very much more economical results were obtained. He could not agree with Mr. Crompton that the losses in the feed pumps were due to the intermittent way in which they were worked, in fact a feed pump ought to supply a continuous feed, as was generally recognised in boiler rooms. He thought it was probably a slip that had caused Mr. Crompton to state that he had obtained at Chelmsford an efficiency of 76 per cent. which he said was as high as had been reached by any system of alternate current distribution, while a few lines further on he gave the efficiency of the City of London Company as 82 per cent. In connection with this question of efficiency of distribution, he would point out that while with the direct current low tension system this dropped as the load factor increased, on the transformer sub-station system the efficiency increased with the load factor. Before concluding he would like to ask Mr. Crompton why he had not taken advantage of the high thermal efficiency of gas engines in order to bring down his coal consumption. It was well known that less than one pound of coal with gas-producing plant sufficed to produce one horse-power, therefore 1¼ lbs. per unit, or allowing for losses in distribution, 1½ lbs. per unit sold should cover fuel, as there was no loss in pipes due to radiation. His experience of modern gas plants showed that, considering the reduced cost of buildings and absence of chimney, the first cost was not far different from that of steam engines and boilers. As there was no difficulty in running alternators in parallel off properly arranged gas engines, the above figures were sufficient to show that there was at least potentiality in this source of power for electricity supply purposes.

(To be continued)

ECONOMY IN STEAM GENERATION.

UNDER this title our Chicago contemporary, *Electrical Engineering*, discusses the cost of generating steam under various conditions as to fuel and plant, and gives four tables that have been used for the purpose by R. W. Hunt & Co.

The first table gives the cost of evaporating 1,000 lbs. of water with coal at from 3s. to 16s. per ton, at which latter price, even with an evaporation of 11 lbs. of water per pound of coal, it is noted that coal of only 5 lbs. evaporative duty, and costing 7s. per ton, is cheaper. We have always insisted that from a mere question of cost the cheapest fuel that can be burned is generally the most economical commercially, though we are fully aware that we are not in accord with a very widely expressed opinion to the contrary. By cheap fuel we would understand fuel that is cheap because of its smallness, *e.g.*, dust coal, but not fuel that is largely composed of dirt. In England oil has not yet become at all a common fuel, though in America it is rapidly coming into use. It is probable that as our facilities for importing oil in bulk are improved, we shall find it coming more into use for steam raising. Table 2 gives the cost of evaporation, using oil at a cost of 10d. to 4s. 2d. per barrel, with an evaporative duty of from 10 to 20 lbs. of water.

This table shows that with a duty of 14 lbs. evaporation, oil at 1s. 8d. per barrel is equal to coal at about 6s. per ton, which will evaporate 8 lbs. only.

Table 3 gives the labour cost per 1,000 lbs. evaporated when coal is used, and Table 4 when oil is the fuel. These latter tables are worked out for boilers of 75 to 600 horse-power, and from one to ten boilers in a battery. By combining for any given case the two sets of results of fuel cost and labour cost, it can be determined which of two methods is likely to prove the better.

Apropos of fuel and the use of oil or coal, it may be pointed out that in the event of the failure of any one fuel, the results may be extremely inconvenient. We know of an instance of a set of boilers being fitted with mechanical stokers, made to burn a specially fine slack coal, and when for some reason a supply of the coal was not forthcoming, the works had to be stopped, for the machines would not deal with the lump coal that was alone available. It is for such reasons that a combined system offers a great advantage. On the locomotives of the Great Eastern Railway, coal or liquid fuel can be used promiscuously, and the change from one to the other made instantaneously, without the slightest trouble.

No one who has watched a well-designed liquid fuel furnace at work can have a doubt as to the advantages conferred by such fuel in accommodating the intensity of the fire to the rate of steam using or work performed. This can never be done so effectually with solid fuel, because the large mass of fire on the grate remains after the intensity of combination has been checked. With oil fuel there is no great mass of fire; cut off the oil, and the supply of heat is also nearly stopped.

AN ESTIMATE OF THE DISTANCE TO WHICH NIAGARA WATER-POWER CAN BE ECONOMICALLY TRANSMITTED BY ELECTRICITY.*

BY EDWIN J. HOUSTON, PH.D., AND A. E. KENNELLY, F.R.A.S.

ONE of the most important questions of the day is, how far is it commercially possible to transmit water power electrically? It is recognised that the limiting commercial distance depends upon two associated interdependent factors; viz., cost and electric pressure.

1. *Cost*, including the purchase and maintenance of the necessary machinery and wires, together with the annual interest chargeable upon such expenditure.

2. *Electric Pressure.*—The pressure or voltage at which the line transmitting the power can be operated with continued security to life, and assurance of permanence of supply, and permanent protection to the lines of conductor from lightning, weather, and all disturbances.

It is clear that if reliable machinery could be purchased cheaply enough, and the conductors could be safely operated at sufficiently high pressure, the Falls of Niagara could to-day stop steam engines in New Orleans, La., by under-selling their power.

Up to the present time the commercial distance at which water power has been distributed is only about 25 miles, and the distance to which it might be distributed commercially under ordinary conditions has been generally regarded as a radius of 50 miles.

In one sense the celebrated exhibition in 1891 of the transmission of about 200 H.P. from Lauffen to Frankfort, acted as an incentive to long distance electrical transmission, since it revealed the capability and feasibility of the system; but at the same time this notable experiment has, perhaps, also retarded the progress of the art it was designed to foster;

* New York *Electrical Engineer*.

for the cost of installing the entire plant of turbines, generators, aerial conductors and transformers, is said to have been $84,600. The apparatus was designed for 300 H.P. (223 kw.), and this would represent an installation cost of $378 per kw. ($282 per H.P.) delivered in Frankfort. It appears, however, that not more than 200 H.P. was ever continuously delivered, making the cost $423 per H.P. ($567 per kw.). The annual cost of producing this power in Frankfort, with a steady load of 150 kw. day and night at motor shafts, could hardly be less than $100 per kw. ($74.60 per H.P.) delivered, commercially, a prohibitory rate. The distance from Frankfort to Lauffen is 109 miles, the voltage between tri-phase conductors 13,000 to 30,000, and the frequency 40 ~.

Seeing that the Lauffen-Frankfort electrical transmission experiment, the only one over 25 miles in distance yet attempted, although it was a great success from an engineering standpoint, would be a failure commercially, it becomes important to ascertain how far, in the near future, power can be electrically transmitted from Niagara Falls at commercial rates. There must be a certain radius from Niagara, within which electrical power will carry death and displacement to the ordinary steam engine, and it is desirable to ascertain how far this radius may be likely to extend.

We shall first assume that a steady transmission of power is to be provided for, from Niagara Falls to various cities along the banks of the Erie Canal, as shown in the accompanying table.

The system of transmission must first be decided upon before the details of cost can be approached. It is quite possible that at some future time continuous current generators and motors can be worked up to a total pressure of 50,000 volts. At the present date, however, such pressure cannot be guaranteed with continuous current machines. With alternating current apparatus, we have to choose between uni-phase, di-phase with common return, and tri-phase systems. It can be shown that where the voltage on the line is so high that a certain value, say 50,000 volts at the receiving end, has to be assigned as a safe limit to the maximum pressure between any two conductors, the tri-phase system is the most economical of the three. We shall, therefore, assume this pressure limit and tri-phase at a frequency of 40 ~.

This maximum pressure of 50,000 volts represents for sinusoidal waves an E.M.F. of 35,350 volts between wires, or an equivalent pressure of 20,410 volts effective from each wire to the neutral point. This is a pressure but slightly in excess of that successfully used in part of the Lauffen-Frankfort experiments (30,000 volts between conductors), and may, therefore, be reasonably assumed as practicable.

The nature and disposition of the conductors is a most important consideration from an engineering standpoint. Three methods have been advocated at different times.

1. *The Conduit method*, in which insulated cables are buried in underground pipes containing air or filled with oil :—

Distance.	Miles.	K.W.	H.P.
To Buffalo	15*	22,500	30,160
To Syracuse	164	7,500	10,060
To Schenectady	300	7,500	10,060
To Albany	330	15,000	20,110
To various points along canal, for barge propulsion ...	...	15,000	20,110
		67,500	90,500

* To outskirts of Buffalo city.

2. *The Subway method*, in which wires are carried on brackets in an underground passage, such as that which connected Machinery Hall with the Manufactures and other buildings in the Chicago World's Fair, room being left for an inspector to patrol the passage way.

3. *The ordinary Aerial Line method.*

Within city limits, there can be no question that either the first or second method is necessary to ensure perfect safety from accidental contacts with high pressure conductors. But in the open air, for example, along the banks of the Erie Canal, the overhead line is by far the cheapest method. Moreover it is not only safe, but is also readily inspected or repaired. Also for distributing power on such a scale as that here considered, a pole line construction can be adopted that would be strong enough to resist time, and defy storms either of lightning or sleet. Overhead lines were employed between Lauffen and Frankfort, and are employed in all the long distance electric transmission systems yet constructed.

We shall now assume that the engineering difficulties can all be overcome by bare, overhead, tri-phase wires at 35,350 volts receiving pressure, with step-up and step-down transformers at each end of the lines. It remains now to consider only the question of cost.

Turbines and Hydraulic Works.

We require to estimate the annual cost of producing one kilowatt steadily at the turbine shafts at Niagara Falls. It has been stated that the estimated cost of the hydraulic works at Niagara for a total of 119,000 H.P.,

Was	$10.50 per H.P.	or $14.070 per kw.*
If we add as much as 20 per cent. for any possible miscalculation	2.10 „ „	2.814 „
And also add cost of turbines at	5.00 „ „	6.703 „
	$17.60	$23.587

Allowing 5 per cent. for interest on capital, 2½ per cent. for superintendence and repairs, and 2½ per cent. for depreciation, the total annual cost is 10 per cent. on investment, or $1.76 per H.P., or $2.359 per kilowatt, assuming that the turbines are always running at full load. This, however, is more than can reasonably be expected. The average load under favourable conditions can hardly exceed 60 per cent. of the maximum load handled, making the annual cost $2.932 per H.P. or $3.931 per kilowatt of average annual delivery.

Another line of reasoning is as follows :—It has been stated by Prof. Forbes † that he did not continue to add cost to his generators, when $60 of extra expenditure in them did not increase their electrical output by 1 H.P. Prof. Forbes also mentions ‡ that he took 5 per cent. as interest on investments, so that it seems clear that his estimate of the annual cost of producing one horse-power at generator terminals is 5 per cent. of $60, *i.e.*, $3 per H.P. or $4.021 per kw.; and eliminating the cost of generators, this would be about $3.72 per kw. at turbine shafts. However, as our purpose is to be conservative, it may be safer, in the absence of actual assurance, to take $4.00 per kw. as the cost of power at turbine shafts per annum ($2.984 per H.P.).

Generators.

The cost of alternators, as is well known, varies greatly with their size and capacity. In sizes below 3 kw. their purchasing cost may be $100 per kw., while in sizes of, say, 50 kw. they may cost $45 per kw. Finally, in very large sizes, say of 4,000 kw., their purchasing cost would probably be reduced to $8.516 per kw. ($6.352 per H.P.), including exciters, and all station apparauts.

Motors.

The cost of motors may be expected to average slightly higher than that of generators, for the reason that they will frequently require to be made in smaller sizes (say for 1,000 kw.) than the generators. The purchasing cost per kilowatt may be taken as $9.581 per kw. ($7.146 per H.P.) with exciters and apparatus included.

Transformers.

The step-up and step-down transformers would probably not cost more than $5.157 per kw. ($3.847 per H.P.). Prof. Forbes has stated that offers as low as $3.52 per H.P. ($4.72 per kw.) have been made to deliver such transformers.§ These transformers may be conveniently regarded as forming part of the generators or motors at each end of the lines. In this regard, allowing 0.96 as the efficiency of

* *Transactions*, American Institute of Electrical Engineers, March, 1893, Vol. x., p. 154.

† *Journal*, Institution of Electrical Engineers, Vol. xxii., No. 108, December, 1893, p. 615.

‡ *Ibid*, p. 516.

§ *Ibid*, p. 495.

generators or motors, the purchasing cost of generators and all accessories becomes $13.888 per kw., or $10.352 per H.P. Purchasing cost of motors, $14.953 per kw. or $11.154 per H.P.

The efficiency of complete generator and motor plants becomes 0.94 at full load, allowing 0.98 as efficiency of transformers.

Conductors.

It is obvious that the right amount of capital to expend in line conductors and construction, after the voltage and frequency have been decided upon, is such that additional expenditure just ceases to save its value in interest, by reason of the consequent reduced loss of power in the line. In cases where the expenditure in the line and construction is in proportion to the weight of copper in the line, this economical point must be attained when the annual charges of interest, repairs and depreciation on the whole line are equal to the money value of the power lost in transmission along the line, which is Kelvin's law, and is applicable to alternating as well as to continuous currents, and whether such currents have lag or not. Usually, however, the expenditure upon the line does not increase directly with the weight of conductor, and the first statement is, therefore, more generally applicable than Kelvin's law. It can be shown that, with the prices above mentioned, the most economical weight of copper to employ on each main tri-phase conductor will be about 20½ lbs. per ampère per mile.

Allowing for the best quality of oil insulators and bare wires, not exceeding No. 000 A.W.G., a first-class ordinary pole line can be erected for $1,000 per mile of line, and if this allowance be made for the line to each city, the combination will admit of a substantial and permanent structure in wood or in iron, capable of holding all the wires safely, and in a manner practically safe from lightning, yet readily accessible to linemen for repairs. By properly grading the distances between conductors, the antagonistic effects in the lines of capacity and inductance can usually be rendered negligible, so that the fall of pressure in the lines becomes that simply due to ohmic resistance. By systematically transposing the wires of all circuits, say, at every mile, their mutual inductance would be negligibly small, and their capability of disturbing one another would be consequently annulled.

Superintendence and Operating Expenses.

The following staff might be expected to handle the system :

One general superintendent and assistants	$30,000	per annum.
One chief engineer	20,000	„
Twelve assistant engineers	36,000	„
Forty dynamo assistants	40,000	„
Forty linemen and assistants	40,000	„
	$166,000	„
Office expenses, salaries, taxes, &c. ...	34,000	„
Total	$200,000	„

Or $2.00 per H.P. of total capacity, or $2.681 per kw.

Albany.

Distance, 330 *miles; Maximum delivery*, 15,000 *kw.*

For a delivery with full load at motor shafts of	1.000	kw.
The delivery at line terminals	1.064	„
And with a power factor of 0.9, the received current on each conductor is	0.01931	amp.
Copper per mile on each conductor	0.3958	lb.
Total copper in line, per kw. delivered ...	391.9	lbs.*
Approximate loss of energy in line	0.862	kw.
Approximate energy delivered at Niagara terminals	1.926	„
Approximate energy delivered at Niagara turbines	2.048	„
Cost of 1.926 kw. generator at Niagara, at $13.888 per kw.	$26.750	per kw.
Cost of 391.9 lbs. of copper in lines	48.987	„
One kilowatt motor at Albany, at $14.953 ...	14.953	„
	$90.690	„
Cost of 330 miles of line at $1,000 for 15,000 kw.	22.000	„
Total investment per kw. delivered ...	$112.690	„
Annual cost of interest, depreciation and repairs, at 10 per cent.	11.269	„
Cost of 2,048 kw. at turbine shafts, at $4 ...	8.192	„
Labour, superintendence, and general expense	2.681	„
	22.142	
Annual cost of delivery of 1 kw. at sustained full load	$22.142	per kw.
At average of 60 per cent. of full load, $27.53 per H.P. or	$36.903	„

* The number of wires in the lines to Albany would be nine, about No. 000 B. & S. gauge, three on each main conductor.

Syracuse.

Distance, 164 *miles; Maximum delivery*, 7,500 *kw.*

For a delivery with full load at motor shafts of	1.000	kw.
The delivery at line terminals	1.061	„
And with a power factor of 0.9, the received current on each conductor is	0.01931	amp.
Copper per mile on each conductor	0.3958	lb.
Total copper in line, per kw. delivered ...	194.8	lbs.
Approximate loss of energy in line	0.4286	kw.
Approximate energy delivered at Niagara line terminals	1.4926	„
Approximate energy delivered at turbine shafts	1.588	„
Cost of 1.4926 kw. at Niagara, at $13.888 per kw.	$20.730	per kw.
Cost of 194.8 lbs. copper in line, at 0.125 ...	24.350	„
Cost of 1 kw. motor at Syracuse, at $14.953 ...	14.953	„
Total	$60.033	„
Cost of 164 miles of line, at $1,000 for 7,500 kw.	21.87	„
Total investment	$81.903	„
Annual cost of investment at 10 per cent. ...	8.190	„
Cost of 1.588 kw. at turbine shafts, at $4 ...	6.352	„
	$14.542	„
Labour, superintendence, and general expense	2.681	„
Annual cost at sustained full load, $12.85 per H.P., or	17.223	per kw.
Annual cost at 60 per cent. full load, $21.414 per H.P., or	$28.705	„

Buffalo.

Distance, 15 *miles; Maximum delivery*, 22,500 *kw.*

For a delivery with full load at motor shafts of	1.000	kw.
The delivery at line terminals	1.064	„
And with a power factor of 0.9, the received current on each conductor	0.01931	amp.
Copper per mile on each conductor	0.3958	lb.
Total copper in line per kw. delivered... ...	17.82	lbs.
Approximate loss of energy in line	0.0392	kw.
Approximate energy delivered at Niagara line terminals	1.1032	„
Approximate energy delivered at turbine shafts	1.174	„
Cost of 1.1032 kw. at Niagara, at $13.888 per kw.	$15.320	per kw.
Cost of 17.82 lbs. of copper in line, at $0.125	2.228	„
Cost of 1 kw. at Buffalo, at $14.953 per kw. ...	$14.953	„
	$32.501	
Cost of 15 miles of line, at $1,000 for 22,500 kw.	0.667	„
Total investment	$33.168	„
Annual cost of investment at 10 per cent. ...	3.317	„
Cost of 1.174 kw. at turbine shafts at $4 ...	4.696	„
	$8.013	„
Labour, superintendence, and general expenses	2.681	„
Annual cost at sustained full load $7.978 per H.P.	$10.694	per kw.
Annual cost at 60 per cent. full load $13.296 per H.P.	$17.823	

Summary.

Cost of delivering a max. of 22,500 k.w. at Buffalo	at $10.694			$240,610
Cost of delivering a max. of 7,500 k.w. at Syracuse	„	17.223		129,170
Schenectady	7,500	„	21.260	159,450
at Albany	15,000	„	22.142	332,130
different points	15,000	„	17.830	267,450
	67,500			$1,128,810
Average cost of delivery, full load	$12.475	per H.P.		$16.723 per kw.
Average cost of delivery 0.6 full load	$20.792	„		$27.872 „
By Emery's tables the cost of generating steam power per annum with coal at $3 per ton is for 308 *days of ten hours*	$25.27	„ and		$33.88 „
365 days of 20 hours ...	$44.43	„	„	$59.56 „

This is with large triple expansion compound engines.

CONCLUSION.

The foregoing results indicate that on the basis of prices and voltages assumed and detailed, the power of Niagara Falls can be transmitted to a radius of 200 miles, cheaper than it can be produced at any point within that range by steam engines of the most economical type with coal at $3 per ton. That Niagara power can maintain at Albany a large day and night output cheaper than steam engines at Albany can develop it, but that for power taken at Albany for 10 hours per diem the best steam engines have somewhat the advantage over Niagara unless exceptionally favourable conditions of load could be secured for Niagara power.

These conclusions are, of course, entirely dependent upon the reliability of the prices, voltages and estimates as detailed above. The prices, however, appear to be conservative, and are probably in excess of the latest market values. This would also appear from the statement recently published that the Cataract Construction Company has contracted for the privilege of right of way for conducting lines along the Erie Canal banks, by supplying power for barges at the annual rate of $20 per H.P. ($26.81 per kilowatt), whereas the above figures make the average cost of production $20.792 per H.P. ($27.872 per kw.) on the basis of an average output of 0·6 full load; so it would appear that the Niagara Power Company are in the possession of better prices. Moreover, if the voltage delivery on the long lines, here taken as 35,350 at the receiving end, can ever be safely increased, a marked reduction in the cost of delivery would naturally result.

The broad conclusion to which an inquiry of this nature inevitably leads, is that while under ordinary conditions the commercial limit of electrical transmission of power from water powers of less than 500 kilowatts can hardly exceed 50 miles, the radius at which it will be profitable with good fortune and management, to electrically transmit a water power aggregating 50,000 kw., or more, is, perhaps, to-day, 200 miles, and that it might be commercially advantageous for such a large water power to undersell large steam powers at twice this distance with no profit, in order to reduce the general expense upon delivery nearer home. The reason for this difference in the transmission radius between small and large water powers, lies obviously in the fact that electrical and hydraulic machines can be built and purchased much more economically in large sizes than in small, so that the cost of producing and of maintaining 1 kilowatt is very much less for large than for small water powers.

Laboratory of Houston & Kennelly,
Philadelphia, *April 13th*, 1894.

NEW PATENTS—1894.

8,500. "Electrical connector for making insulated joints under water or clay between cable or other insulated wires." H. R. VEREKER. Dated April 30th.

8,512. "Improvements in and connected with insulators for overhead electrical conductors." A. WIGLESWORTH. Dated April 30th.

8,525. "A method of overcoming induction on telephone and transmitting lines." A. G. WATERHOUSE. Dated April 30th.

8,534. "Improvements in electrically-propelled vehicles." W. C. BERSEY. Dated April 30th.

8,539. "Improved telephone and exchange system." E. ANDREOLI. (Communicated by P. E. Raverot and G. A. Hess, France.) Dated April 30th.

8,548. "Improvements in the construction of spring reels for roses for ceilings or wall connections and other electrical fittings." K. W. HEDGES. Dated April 30th.

8,552. "Improved commutator brush." R. KERSBERG. Dated April 30th. (*Complete.*)

8,556. "An improved electrically operated door chain or the like." E. STOESSEL. Dated April 30th.

8,566. "Improvements in alternating and multiphase current dynamos." T. PARKER. Dated May 1st.

8,567. "Improvements in brushes and brush-holders for electric generators and motors." W. H. SCOTT. Dated May 1st.

8,579. "Improvements in oil and gas motor engines." W. L. P. WEBB. Dated May 1st.

8,585. "Improvements in electric conductors for underground conduits." D. E. CONNER. Dated May 1st. (*Complete.*)

8,587. "Improvements in and relating to electric railways." H. H. LAKE. (Communicated by W. B. Purvis and M. M. Armstrong, United States.) Dated May 1st. (*Complete.*)

8,599. "Improvements in electric arc lamps or lighting apparatus." J. B. MCKEOWN. Dated May 1st. (*Complete.*)

8,607. "Improvements in or appertaining to electrical exchanges." W. P. THOMPSON. (Communicated by A. E. Keith, United States.) Dated May 1st. (*Complete.*)

8,613. "Improvements in or appertaining to automatic electrical exchanges." W. P. THOMPSON. (Communicated by The Strowger Automatic Telephone Exchange, United States.) Dated May 1st. (*Complete.*)

8,617. "An electric-alarm bag." T. N. WHITE. Dated May 1st.

8,634. "Improvements in the means for controlling electric lamp circuits from a distance." J. C. FELL. (Communicated by R. H. Postlethwaite, New Zealand.) Dated May 1st.

8,638. "Improvements in alternating current, simple or polyphase, dynamo-electric machines." S. PITT. (Communicated by André, Blondel, and Sautter, Harlé et Cie., France.) Dated May 1st. (*Complete.*)

8,654. "Improvements in apparatus used as brackets or chandeliers for electric light." R. N. GRENVILLE and S. H. TERRY. Dated May 2nd.

8,668. "Improvements in oil or gas engines." T. C. HOGG and J. GROVE. Dated May 2nd.

8,730. "Improvements in and connected with supports for electrical batteries used on vehicles and the like." T. FROGGATT. Dated May 2nd.

8,731. "Improvements in electric batteries." T. FROGGATT. Dated May 2nd.

8,733. "Improved electrical fire and burglar alarm." H. DAWSON. Dated May 2nd.

8,761. "Improvements in and connected with electric fire alarms." A. ARCHIBALD and G. TARBY. Dated May 3rd.

8,773. "An automatic electric fire-alarm time call." F. H. DENNIS. Dated May 3rd.

8,794. "New or improved electrical appliances enabling trains in motion to have constant and direct telegraphic communication with the stations or other trains on the same line." P. E. M. BASTION. Dated May 3rd.

8,795. "An improved holder or support for the receivers of telephones." A. CONNELL. Dated May 3rd.

8,807. "New or improved means for protecting magnetic needles from local attraction." J. S. GIBBORNE. Dated May 3rd.

8,808. "Improvements in electric batteries." R. MCL. MCDONALD and A. MCDONALD. Dated May 3rd.

8,812. "Electrical jacquard apparatus for looms." SIEMENS BROS. & CO., LIMITED. (Communicated by Messrs. Siemens and Halske, Germany.) Dated May 3rd.

8,813. "Improvements in electric conductors." SIEMENS BROS. and Co., LIMITED, and W. DIESELHORST. Dated May 3rd.

8,815. "Improvements in electrolytic cells." L. MOND and R. L. MOND. Dated May 3rd.

8,823. "Improvements relating to the transmission of signals through telegraph lines and cables." J. A. L. DEARLOVE. Dated May 3rd.

8,825. "Improved means for conducting electricity through tablecloths, carpets, and the like to electric lamps and other electrical devices." THE ELECTRICAL INSTALLATION COMPANY, LIMITED, and E. L. O'BRIEN. Dated May 3rd.

8,835. "Improvements in the electrical propulsion of cars." W. J. STILL. Dated May 3rd. (*Complete.*)

8,838. "Improvements in fuses or cut-outs for electric lines." J. PILLISCHER. Dated May 3rd.

8,845. "Harness collar for carrying the electric light on harness." J. L. PHIPPS. Dated May 4th.

8,895. "Improvements in or connected with secondary or electric storage batteries." F. KING. Dated May 4th.

8,896. "Electrical apparatus for preventing collisions and other accidents on railways." A. JOSEPH. Dated May 4th.

8,917. "Improvements in or in connection with apparatus for the electro-deposition of metals." H. ALEXANDER. Dated May 4th. (*Complete.*)

8,924. "Self-contained electrical generating apparatus and driving mechanism." C. LANGSTONE, B. YOUNG, and J. A. EWINS. Dated May 5th.

8,972. "Improvements in or relating to secondary batteries." F. GRIFFIN. Dated May 5th.

8,976. "Improvements in submarine telegraph cables." W. S. SEATON. Dated May 5th.

ABSTRACTS OF PUBLISHED SPECIFICATIONS, 1893.

2,267. "Improvements in the method of and apparatus for the electrolytical separation of the bases of salts and of compounds of the same from saline solutions." C. T. J. VAUTIN. Dated February 1st. The inventor employs a sieve of suitable material, such as horsehair, silk wire, &c., or any material not acted on by either the electrolyte or mercury, upon which is supported a layer of mercury, which forms the cathode, and under which is preferably immediately arranged a suitable anode. 5 claims.

4,938. "Improvements in incandescent electric lamps." G. S. RAM. Dated March 7th. Consists in making the terminal end of the lamp concave or cup-shaped. 1 claim.